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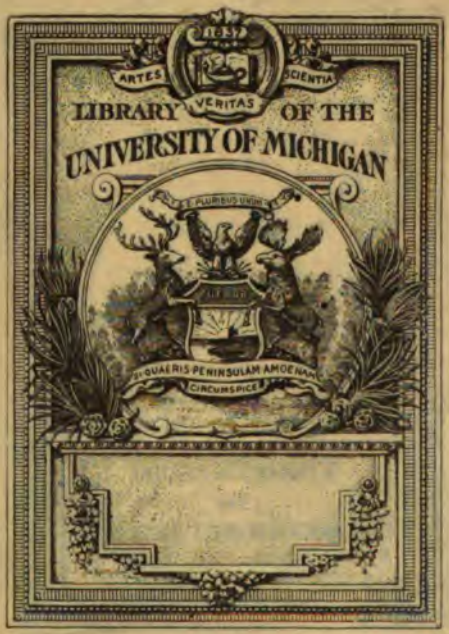

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OF THE

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EIGHTH ANNUAL MEETING

OCTOBER 15, 16, 17, 1913

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SECTION B.

Section B. of the American Gas Institute held at the Jefferson Hotel, Richmond, Va., Thursday, October 16, 1913, was called to order at 10 A. M. by the second Vice-President, Mr. C. N. Stannard of Denver.

THE CHAIRMAN: I will ask Mr. Vincent to act as Secretary on this occasion. The first on the program is, The Installation of Cast Iron Street Mains, by Walton Forstall.

Mr. Walton Forstall then read the abstract of his paper on the above subject.

THE INSTALLATION OF CAST IRON MAINS.

Abstract.—This paper considers in great detail the installation of cast iron bell and spigot mains for low pressure distribution. It does not describe any equipment, nor does it contain any reference to the designing or maintenance of a street main system. It is written mainly with the idea of aiding the beginner to obtain a certain knowledge of main laying in a shorter space of time than might be possible were he obliged to depend on verbal instruction and daily experience.

It begins with the proper organization of a main laying staff, from the superintendent to the laborer, with the duties of each one in the chain, and how these duties are affected by the size and character of the operation. The composition of main laying gangs under various conditions is given. The work preliminary to trench opening, such as pre-inspection of site, delivery of material, nature and location of equipment, are described. Then follows the removal of various kinds of paving and the separate disposal of the different kinds of excavated material. Under trenching, the protection of the public by barriers and bridges, of the workman by shoring, and of the trench from water damage, is considered, and the best arrangement of the digging gang, both for earth and for rock. The actual laying of the pipe includes the organization of laying gangs for large and for small pipe, the individual duties of each man; the progress of a length from the

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street surface to its final resting place in the line; and the laying of a branch, a hub split sleeve and a hat flange. Under jointing, there is a detailed description of yarning and of making lead and cement joints, with the various precautions to be observed in the use of the latter material. Lead wool is only touched on. Several ways of testing joints are mentioned.

Blocking is recommended as a precaution against settlement. The bagging off of gas supply is thoroughly gone into, including the points that must be borne in mind to prevent any underground interruption in gas supply. Two methods of purging mains are described. The maintenance of gas supply during main replacement is explained for three different conditions.

Various methods of refilling trenches are considered and a strong plea made for a prompt and thorough cleaning up after work completion. Repaving as applied to various classes of road surfaces is discussed, with a consideration of the arguments for and against the employment of a paving contractor. A list of paving equipment is given.

The recording of main work is described at length. A method is given for a system of new mains only, one for old mains only, and a third applicable to both new and existing mains.

The paper concludes with a discussion of the reasons for, the location and design of, and the inspection of mains on bridges, under surroundings usually met with in cities.

INTRODUCTORY.

The design of this paper is to describe in great detail the installation of street mains, including the requisite organization of the main laying force. It is meant primarily for the learner in distribution work, but the writer hopes that it will be of some assistance to older men, if only because it gathers in one place and in logical order, information that hitherto has not been thus available, concerning American distribution practice. As the paper forms part of, and is taken from, a much larger work, it contains no reference to the designing or maintenance of a street main system nor does it describe the equip-

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ment generally used. The inclusion of these subjects would have added too much to the existing many pages.

It is hoped that the early appearance of the paper will be taken advantage of by our distribution engineers generally, and that they will be prepared to discuss it fully in October, so that when it is embodied in the proceedings, it will represent not merely the ideas of one man or set of men, but, as interpreted in the light of the criticisms which undoubtedly it deserves, and should get, it will become a useful treatise on its particular detail of distribution practice.

ORGANIZATION FOR WORK.

SMALL TOWNS.

The proper organization of a force for the work of main laying will vary according to local conditions, as the sphere of operation is first, in a small town, or the growing fringe of a large city; or second, in the congested portion of a large city. It will also vary somewhat in any particular locality, with the length and size of the main being laid, whether small, *viz.*, 12″ or under, or large, *viz.*, 16″ or over. (In the future, the words small and large will be used in this sense when referring to main work.) In any event, the street main work should be under one man who, whether the superintendent himself (as would be the case in many companies) or not, will be considered for our purpose as being called the general main foreman, and will be referred to as the main foreman.

In the first case spoken of above, *viz.*, a small town, or the growing fringe of a large city, the duties of the main foreman will be very general. He will make a prior inspection of all locations where work is to be done, plan the work, decide perhaps upon the character of and arrange for the delivery of the specials to be used, as well as all other material, exercise a general oversight while the work is being done, and inspect the site

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after completion. In some instances, he will act as timekeeper and also check any reports made out by the gang foreman.

If the work consists almost entirely of laying mains to supply row after row of houses, or, as they are called in Philadelphia, "building operations," as the majority of these operations are begun in the spring and finished in the fall, and the most economical organization of the main force is that of a constant number of men, able, by working three hundred days in the year, to lay the miles of mains required annually, then, in order that the main and service work shall always be finished when gas is needed, or, as is more usual, when the builder is ready to pave street and footway, it often becomes necessary to lay a main in some streets soon after the house foundations are begun. This will sometimes mean that the proper line and grade stakes must be obtained from the city surveyor, and then the main foreman takes the gang foreman to the location and gives him, with reference to the stakes, all the information necessary in regard to opening trench. The two foremen also decide upon the best starting point and any other details in regard to the work, such as the proper character and location of the necessary specials, including drips, for under the conditions being described, there will be few underground structures encountered to cause unexpected changes in plan. As mentioned before, the delivery of this and any other material, and of tools and equipment will come directly under the supervision of the main foreman, and if the team used is also employed in hauling material for service work, the main foreman will make all his plans for this team in conjunction with the service foreman, in order to insure its most economical use each day.

Where the recording of main work is done by the main department, the main foreman will generally make the necessary sketches, assisted by the gang foreman for such portions of main as may be laid and covered up in the absence of the main foreman.

To sum up, in the conditions now being described, the main

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foreman plans the movement of, and lays out in detail, the work of each main gang, and the gang foreman handles his men to get the designated work done with the greatest possible despatch and efficiency.

The composition of each individual gang will depend largely upon local conditions. For the Philadelphia work, in the growing fringe, where most of the laying is 6″ in dirt streets, and the average job is one block, or about five hundred feet, the following personnel has been used to great advantage:

1 gang foreman
2 caulkers
2 caulkers' helpers
14 laborers

In warm weather, a water boy should be employed to enable the men to keep steadily at work, and not be continually leaving the trench to walk to the water pail, disorganizing the work.

Experience has shown that with a good organization and a competent foreman, a small gang of this kind will turn out a splendid amount of work per man. Each laborer becomes a picked man and is worth the extra pay he gets. It is also surprising, if the proper brains be directing the main work, how constant may be the number of laborers to take care of what would seem to be a very fluctuating amount of building operations, as measured by the number begun each month. It is needless to say that where a gang is continually changing in size throughout the year, the output per laborer is appreciably lessened.

LARGE CITIES.

The second case spoken of at the beginning of this chapter, *viz.*, where the sphere of work includes the congested portion of a large city, necessitates a change in the mode of working and more of an organization. The main foreman's duties will

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be largely executive, and he can have little detail work to do, as he must be free at all times to go where needed. He will often have to confer with the official of other companies when changes of locations of gas mains, or other structures, are in question, or cases of interference, or damage, have arisen. So much of his time will be taken up in this way that he cannot have very intimate relations with the gang foremen, or lay out their work in detail. He must teach these foremen to be able to decide for themselves in ordinary cases. As he cannot follow any daily routine in his work, he should always keep in touch with his office, so that he can be reached quickly if necessary.

The gang foreman it will be readily seen, should be of a higher type than is needed in situations where the main foreman looks after much detail. While the main foreman will have direct charge of the material delivery teams, the gang foreman will determine the material wanted, and its time of delivery. These orders will usually be telephoned to the office for approval by the main foreman, who, because of his knowledge as to the exact conditions of all his work, is best able to decide upon the details of their execution. Inasmuch as the careful routing of such orders as to distances traversed by heavy or light loads, does not appeal to the average driver, the main foreman is often able, by good routing, to decrease considerably the work of his teams. Beside knowing how to handle his men efficiently, the gang foreman must possess good judgment, not only in ordinary routine work, as for instance, in regard to the amount of trench opened ahead of pipe laying, but also in meeting any peculiar conditions that may arise in the absence of the main foreman. Instant action may be necessary to prevent loss of life, or damage to property, and the gang foreman should be able to act quickly and have a fertile mind, and ability to reason carefully. When the gang foreman is not stationed for the day at any one particular location, he should keep the office in touch with his movements, preferably by telephone.

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Neither the main foreman nor the gang foreman should be expected to make any sketches of the work done. To avoid all possible chance of misunderstanding, no job should be done except on a written order issued by the office and accompanied by a sketch giving in detail all available information necessary for the work.

The personnel of each main gang will be of a fairly high type, especially in caulkers and helpers, because the obstructions encountered and the heavy street traffic make pipe laying difficult. In Philadelphia a gang composed as follows is used:

1 gang foreman
4 caulkers
4 caulkers' helpers
16 laborers

In especial cases of tedious or dangerous work, the whole gang should be composed of experienced men.

For small jobs of changing mains, where backfilling follows immediately upon laying, such as laying around manholes, the gang would be as follows:

1 gang foreman
3 caulkers
2 caulkers' helpers
1 laborer

PRELIMINARY WORK.

PRE-INSPECTION OF SITE.

To insure continuity of work for a main gang, it is necessary to have always planned out ahead, jobs covering a week or ten days. A pre-inspection of each street is essential to ascertain what obstructions may exist along the proposed line of main. Where a building operation is in progress, there are often piles

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of building material, mortar bed, plaster bed, etc. By giving the builder some days' notice of the time for beginning work, he will, especially if he is anxious to have the main laid, arrange to have a clear path for the trench. If is often necessary, however, to see various sub-contractors and to make several calls, and if possible the gang should not be shifted to any location until all obstacles are out of the way.

At this point it will be well to speak about one phase of preliminary work in connection with large main laying, that is peculiar to congested conditions, viz., the ascertaining whether at the location given for the trench, sufficient space will be found. Generally, before a permit is asked for from the City, or perhaps before a route is laid out for the main, test holes have been dug to ascertain the exact location of the existing underground structures. The frequency of these holes and their extent will vary, depending upon the conditions found. If it is apparent that there is plenty of available space, few test holes will be needed. If, however, conditions are very congested in the route and at the location finally decided on, then, unless the preliminary test holes were within one hundred feet of each other, it is advisable at some time before actually beginning the work with a large gang, to open a series of test holes covering two or three blocks, and thus definitely determine the exact location of the trench. It sometimes happens that this will be a zigzag line. As the work progresses, test holes may be opened for the rest of the route. It is always advisable to do this test hole work well in advance of the necessity for trench opening, especially if a change in location requires an application to the City. In length, the test hole should of course cover the space to be explored, and in depth, it should equal the probable depth of trench required. In addition a bar should be driven in several feet at various points in the bottom of the hole to make sure that no structure lies beneath.

DELIVERY OF MATERIAL.

The delivery of material, such as pipe and specials, should

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also be arranged for. Where the force employed in main laying is fairly constant in size for several months, it is comparatively easy to estimate the weekly or monthly need for pipe. As to the yearly need, it has been found possible in Philadelphia to anticipate it very closely, and to place such orders with the foundries that carloads of pipe will be received as wanted, and more than 90 per cent. of the lengths hauled directly from the car to the street. This makes for great economy in handling.

In stringing the pipe, if 12″ or larger, it should be left with bells all pointing the same way, viz., in the direction in which the main will be laid. This direction should be whatever local conditions make most convenient, except where there is a grade exceeding 5 per cent., in which case the bells should always point up hill, reversing direction at each low point and summit. When the pipe is smaller than 12″, it does not pay to add to the expense of loading and unloading by requiring one direction of bells. The pipe should be strung as closely as possible to the curb and on the side of the future trench, except in the case of large pipe when the trench is some distance from the curb, and the excavated material will occupy all the space between curb and trench, so that the pipe must be rolled across the street as needed. Under ordinary city conditions, where the street is open to travel, the pipe must be properly lamped each night.

In addition to the pipe, certain special castings may be delivered on the street prior to beginning work. This is more apt to happen with large mains than small ones, for in the former case, there are often opportunities to economize by hauling the specials directly from the car, while the small specials, being ordered in large quantities, usually before the beginning of active main laying, are at the various store yards. Also, a large main job implies, as a rule, a length of one thousand feet or more, and the use of a minimum number of certain specials no matter what may be the underground conditions. This is not true of the average 6″ job under Philadel-

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phia conditions, where, if laying from an intersection already in place, to the other end of a block, beyond which the development is uncertain, there may be no specials of any kind required. Again, if an intersection is to be laid, it may be known what tees and crosses are required, but the necessity for bends is uncertain, depending entirely on underground conditions, yet to be revealed. Therefore, it may frequently be more economical to deliver no specials until the exact needs of the job are known.

Fig. 1.—Service Cart.

Concerning miscellaneous equipment, such as blocking, cement, lead, etc., it is a mistake to have on the street any more than is necessary to furnish economical hauling conditions from the store yard. Every pound of material left over on a job, to be transferred to the next site, involves unnecessary hauling expenses. Where cement is used, the more that is kept on hand, the more chance of spoiling from storms. One method of caring for small lots on the average job, where a shelter shed is not justified, is to pile the cement bags on the wooden blocks, high enough to avoid possible wetting, and then cover over with a water tight canvas.

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NATURE OF EQUIPMENT.

The normal equipment for a main laying force depends, first, on its size, second, on the character of the main work, including the kind of jointing material used, and third, on conditions of paving and weather (winter or summer). The equipment listed below can be carried in the service cart (Fig. 1), and will suffice for the force described on page 10 when laying 4″, 6″ or 8″ pipe. For larger mains, additional equipment will be necessary.

1 Asphyxiation kit
2 Bags, 4″, 6″ and 8″
1 Bar, leak
1 Bar, rock pinch
1 Bar, search
2 Bars, tunneling
1 Brush, pipe, 4″, 6″ and 8″
1 Bucket, galvanized iron
6 Chisels, cape
6 Chisels, dog
8 Crowbars
1 Cup, drinking
13 Cutters, asphalt
12 Diamond points
Fittings and nipples, assortment
2 Forks, bag
1 Gauge, syphon U
2 Hammers, 14-lb. sledge
1 Hand saw, crosscut
10 Lanterns, red
10 Lantern rods (unless danger signs are used)
1 Level, small pocket
1 Level, 24″
300′ Line, ditch
1 Mattock
1 Oil can, squirt
15 Picks
15 Pick handles
5 Pins, ditch line
1 Pipe, smelling
1 pair Pliers, gas
2 Porters
2 Plugs, wooden, 4″, 6″ and 8″
1 Pump, bag
5 Rammers
6 Rods, canvas screen
1 6′ Rule
3 Screens, canvas
2 Shovels, flat nose, "D" handle
13 Shovels, sharp nose, "D" handle
1 Shovel, sharp nose, straight handle
15 Signs, danger
Soap and brush
2 Stoppers, 4″, 6″ and 8″
Tallowcloth
1 50′ Tape, canvas
1 Tapping machine, combination, with drills
2 Targets, ditch (either type)
3 sets of Tools, caulking
2 Wedges, asphalt
6 Wedges, concrete
6 Wedges, frost
3 Wedges, pipe bursting
1 Wrench, plug
2 Wrenches, Trimo, 14″
10 lbs. Yarn

For Cement Joints.

1 Board, mixing
1 bag Cement
3 prs. Gloves, rubber
1 Sieve, cement, 12″
1 Trowel

For Lead Joints.

3 Bands, pouring, 4″, 6″ and 8″
1 Bellows
1 Furnace, lead
1 Ladle, pouring
25 lbs. Lead

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LOCATION OF EQUIPMENT.

When pre-inspecting the site, the location of such equipment as tool boxes (Fig. 2), tool wagons (Fig. 3), service carts (Fig. 1), etc., is usually determined. When there is much equipment a vacant lot is, of course, preferable to a roadway location. A footway location should be avoided, unless it is wide and little travelled. Ordinarily, an available and suitable location is in the roadway of an intersecting street at an end of a one-block job, or near the center of a larger job.

PREPARING FOR TRENCH.

The occasional necessity for line and grade stakes has been previously mentioned. It is always well to give the surveyor at least a week's notice. When there are no curbs at either side of the street, or at the intersections, stakes are needed. If either side, or intersection, has curb set, by obtaining from the surveyor the width of street, whether straight grade through the block, and if not straight grade, the location and height of the summit, then by means of tape line, level board, tees and targets, the height of curb, and therefore proper depth of trench can be determined accurately enough for most jobs.

The trench is marked out for the width required for the size of pipe being laid, the schedule in use in Philadelphia being as follows:

Size....	4″	6″	8″	12″	16″	20″	24″	30″
Width..	18″	18″	18″	22″	26″	30″	36″	42″

If the street is paved, both sides of the trench are marked with colored crayon, yellow or red preferably. One way of doing this is to locate each side of the trench from the curb every one hundred feet, and then stretch a line between each series of points, first on one side of the trench, and then on the other, marking along the stretched line. If there is no paving, a guide along one side of the trench usually suffices, being given by a rut marked by pick or shovel from a stretched line, or else the line may be left in place on the side opposite to which the excavated material is placed.

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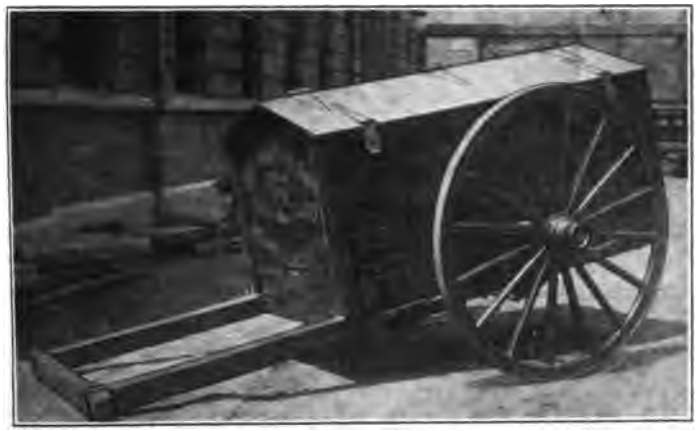

Fig. 2.—Tool Box.

Fig. 3.—Tool Wagon.

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The pipe is also lined up on the opposite side of the trench to the proposed location of most of the excavated material. This ordinarily means that it will be on the side nearest the curb. In lining up, the bells should be pointed in the proper direction, and the pipe should overlap as nearly as possible the exact depth of joint. This will obviate any necessity for shifting pipe lengthways along the trench. Of course, the larger the pipe and the longer the stretch lined at any one time, the more will be the possible saving by careful lining. Where the lining covers the entire job, any shortage or excess of pipe will become evident at once. Where on large mains, the earth is thrown on the curb side, and the pipe strung across the street, it may not be advisable to line the pipe, but simply to roll it across as needed.

REMOVING PAVING

SEPARATING MATERIAL.

On a paved street there are usually several classes of materials to be removed from the trench, and each class should, if possible, be kept more or less separated. Asphalt pieces, or paving blocks, are generally piled, often forming a retaining wall for any large quantity of earth excavation. Bricks or rectangular stone blocks are often of use in making channels for conducting water flow under excavated material. Sand or concrete is kept free from any contact with earth.

In the ordinary case of a small main, the earth would be thrown on one side, and the paving material and base on the other, and the latter might be allowed to lay where it fell, not being in sufficient quantity to interfere with laying operations. Occasionally a streak of gravel, or sand, is encountered, and if it is of value for repaving or for other use, care is taken to keep it separate from the material. Where there is a loose or solid rock, the pieces are generally thrown clear of the earth excavation, so they will not be covered over and can easily be hauled away.

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ASPHALT.

In cutting asphalt, the asphalt screen, Fig. 4, should always be used where there is any danger of injury to property or persons from flying chips. As a rule only one side need be screened, *viz.*, that towards the footway—but if the trench is near a car track with much traffic, and open cars are in use, the track side will need a screen. Support for the screen is obtained by the device shown, and sometimes by tying to trees or poles.

Fig 4.--Asphalt Screen.

Each cut is made by two men working together, using asphalt cutter A, Fig. 5, one cutting right, the other left, and the line marking the side of the trench, forming the center of the cut. Each pair of cutters are spaced eight feet apart, the first pair cutting the right hand line, and the second the left hand line, etc. This staggering of the cutting work enables the whole gang to be closer together, and, therefore, under better supervision by the foreman. With a gang of not more than twenty men, it is advisable to place at work cutting, all the men that tools or space will allow, and finish this work quickly. In any

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case, after all the cutting is finished, one man is given a regulation street broom and sweeps up all the chips, both those inside the screen, and any that may have passed over the screen and lodged on footway or roadway.

If the asphalt is on a concrete base, with both sides cut

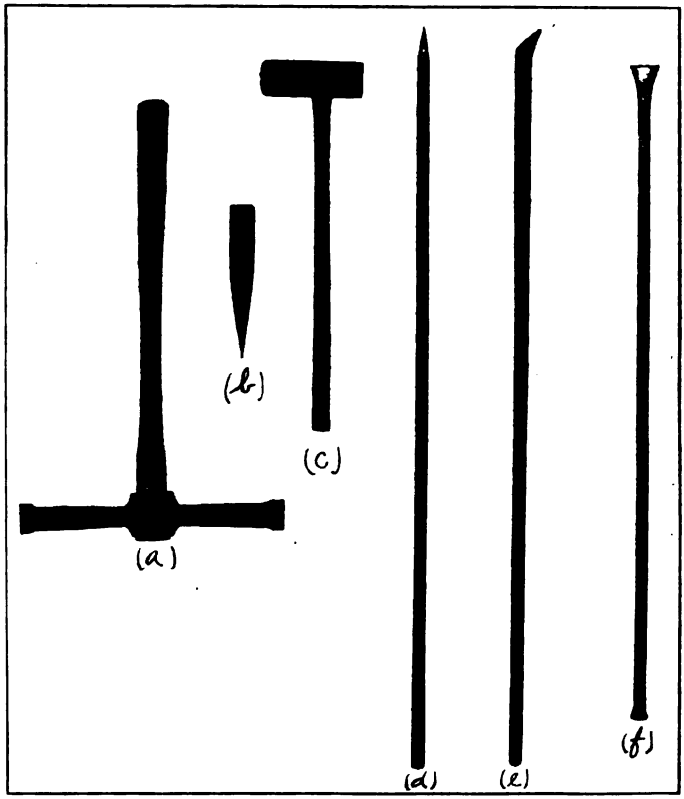

Fig. 5.—(A) Asphalt Cutter. (B) Asphalt Wedge. (C) 14-lb. Sledge for Breaking Asphalt. (D) Bars for Lifting Asphalt. (E) Curb Lever (F) Iron Tunnelling Bar.

through to the base, the asphalt can be lifted off with bars, D, Fig. 5, each lifting gang being composed of four men, *viz.*, two men using the bars, one breaking the asphalt to pieces

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with a 14-pound sledge, C, Fig. 5, and one man carrying away the pieces. As many gangs may be set to work as the width or length of trench will allow room for.

If the base is a rock or bituminous one, the asphalt is removed as follows: Asphalt wedges, B, Fig. 5, are driven in at the bottom of the cut towards the center of the trench, at an angle of 45° with the paving. Four wedges, all on one side, spaced about twelve to fifteen inches apart, are used at one time, driven in for at least six inches, and then loosened by hitting down on the upward turned face of the wedge. At the same time the asphalt is sledged on top at about the centre of the trench. Then the wedges are withdrawn, bars placed in the holes thus left, and the asphalt raised. With the width of trench as opened for small pipe, all the asphalt can ordinarily be thus raised from one side. If not, or on wider trenches, the same procedure of wedging and sledging must be followed on the other side of the trench. It is often advisable to begin to wedge up another section of asphalt before raising all the asphalt that has been loosened. By leaving in the last wedge, a better purchase is obtained on the next section. The gang is composed of six men, three handling the sledges and wedges, one alternating between the bar and the sledge, and two removing the asphalt pieces. At times the three using the sledges will aid on the bar in prying up the asphalt.

On a bituminous base, where the distance between cuts is over thirty inches, the regular curb lever, E, Fig. 5, may often be used to better advantage than the regular bar, D, Fig. 5, in lifting the asphalt after it has been loosened by wedges and sledges.

The asphalt once loosened, is broken up with sledges to a one-man size and piled preferably on the footway along the curb, in heaps about two feet by four feet by three feet high, with centre twelve feet apart.

OTHER PAVING.

Where there is vitrified brick, belgian block, asphalt block, rubble, cobble, or macadam paving, instead of marking the sides

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of the trench by crayon, as before described, an alternative method is to drive in ditch line pins at points one hundred feet apart. Enough paving is removed to make room for the pins, which are driven in at an angle of 45° into the paving, pointing out from the centre of the trench until the head of the pin is almost flush with the paving. In this way the pins will not become loose as excavation proceeds. A line is stretched from pin to pin, and forms the guide for paving removal and for excavating.

For vitrified brick, belgian block and asphalt block, the removing gang is composed of one man barring out paving with the all iron tunneling bar, F, Fig. 5, one man standing in the trench, lifting the paving and throwing it towards the curb, and one man at the curb piling the paving material. For these classes of paving, and also asphalt, it is always best to remove paving by a special gang, and keep this work well ahead of the trenching, in order to avoid using the trenching force on removing paving.

For rubble, cobble or macadam, the trench is laid out in twelve foot sections, and each man removes his own paving with pick and shovel, throwing it off to one side of the trench, any additional moving and piling being done by separate men.

TRENCHING.

PRELIMINARY WORK.

PROTECTION OF THE PUBLIC.

Preliminary to, and also coincident with, the opening of any trench, certain precautions are necessary for the protection of the public, of the workman in the trench, and of the latter itself. Local conditions will determine in each instance just how many of these precautions are required.

Traffic, both roadway and footway across the trench, may have to be provided for. A footway bridge in its simplest form will be one or two planks laid across the trench, battened together, and with a plank on each side to act as a guard.

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This will serve where the traffic is light and the job is of a few days duration. In laying large pipe, or long lines of small pipe, where important streets are opened, the footway bridges should be at least three feet wide and have sides three to four feet high. These bridges are moved from point to point as the work progresses, and six may suffice for even the largest job. No matter what form of bridge is used, attention must be paid to each end to prevent it becoming a cause of stumbling. Earth placed at the end will remove this danger and also hold the bridge in place.

Roadway bridges should be made from 3″ planking. Cross-pieces are placed across the trench about two feet apart, projecting fully two feet into each bank. Planks, parallel to the trench, laid on the cross pieces, form the floor of the bridge, which should not be less than eight feet wide, as measured between the guard railing put up across each end. The floor of this bridge should, as far as is possible, be level with the top of the street. Care should be exercised in making a good joint with the street surface at each approach to the bridge, and earth may be used to good advantage in this, especially where the bridge is somewhat above the paving.

Any trench for large pipe, or a trench for small pipe paralleling a car track, the excavated material in each case being on the curb side, should have a proper guard rail placed along the exposed side. This can be made by laying three or four pieces of 6″ x 6″, or 8″ x 8″, along the trench, about twelve feet apart centre to centre. To each piece a 1″ x 6″, three feet long is nailed as a post, and a 1″ x 3″, or 1″ x 4″ nailed to the top of these posts, forms a top rail. This rail is, of course, fairly flimsy and will need bracing at intervals.

In excavating under car tracks, any paving between the tracks, and for the space of one foot outside each rail, should first be removed and then 3″ plank laid in this space across the trench parallel to the rails, and projecting two feet into the bank on each side of the proposed trench. These planks should

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be flush with the rail and well secured by driving earth in tight at both ends of each plank, after it is in position.

In the provision of bridges, as well as in any other steps necessary to minimize the inconvenience to the public, caused by main work, niggardliness, is apt to be poor policy, and a proper appreciation and provision for the rights of the public is quite compatible with efficient and economical operation.

Fig. 6.—Adjustable Braces for Shoring.

The exact requirement as to free access to fire hydrants will probably vary in different places. Certainly excavated material should be kept at least six feet from a hydrant, and access to it both night and day provided, even if this means a bridge across the trench.

At night the trench and all material should be protected by danger lanterns.

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PROTECTION OF THE WORKMAN.

The principal source of danger to a trench worker, *viz.*, a cave-in, is generally absent in gas main work, because of the shallow trenches usually sufficing. If, however, because of deep excavations or unstable material, (as when the trench lies close alongside of a former trench), there is any question of the stability of the trench sides, the matter of shoring should receive careful attention. Usually a stretcher of 2" x 12", sixteen feet long in one or two lines, he'd apart by adjustable braces, Fig. 6, will suffice. Where sheet piling is required, 1" x 12" boards may be placed back of two lines of stretchers. Naturally, where shoring is resorted to, undue weight should be kept from the trench side, and this may mean in some cases a second handling of material to keep it back from the edge of the opening.

PROTECTION OF THE TRENCH.

Provision should be made to prevent any surface drainage flowing into the trench. Often such drainage must be conducted under the excavated material. At other times damming will suffice to divert surface flow away from the trench. There is no duty of the gang foreman more important than to have his trench protected from the results of violent rain storms. Where underground water is flowing into the trench, a pimp hole should be made, and a pump of either type in Fig. 7 placed in position. In most soils, the presence of water will be very disastrous to the trench sides, so the water must be kept down.

Under this head may be considered the necessity for marking at the trench side, the probable location of any water services crossing the trench. In each case the proper laborer should be shown the mark, and be cautioned to be on the lookout for the service when approaching the proper depth, in order to avoid any chance of injuring it.

EARTH EXCAVATION.

For small mains, the ditch line and pins mark the side of the trench opposite to the excavated material. Each man

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measures off with his shovel a space of twelve feet, and is assigned this space for his work. This sectioning of the work affords an easy way of comparing the relative efficiency of each laborer. In each gang, it is advisable to have one or two men better paid than the rest and expected to serve as pacemakers.

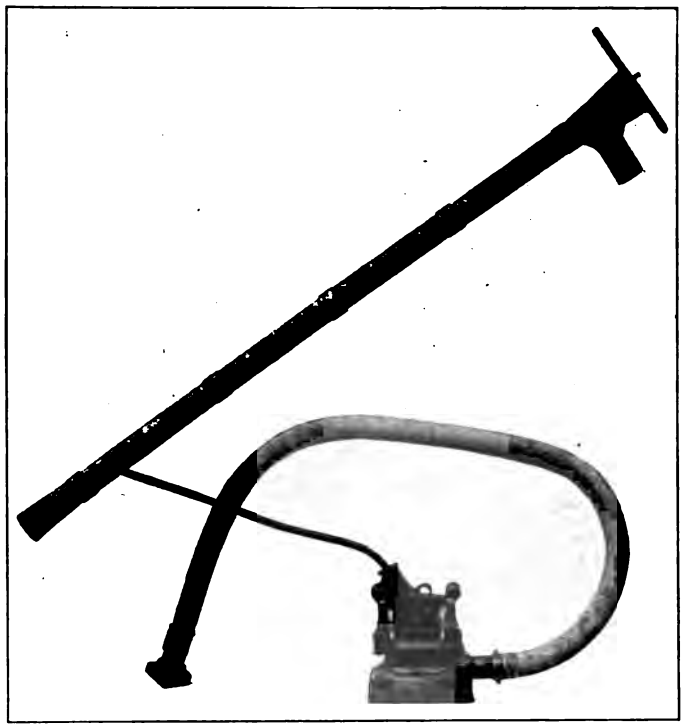

Fig. 7.—Pumps for Removing Water from Main Ditch.

If conditions are alike along the trench, the gang foreman expects all the sections to go down equally fast, and, in practice this pitting of each man against his fellows conduces to high efficiency. The men take more or less pride in finishing first, and the laggards are teased.

For large mains, both sides of the trench are marked by a

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line. For mains up to 16″ inclusive, the diggers are expected to throw the material far enough to render unnecessary any subsequent trimming. For 16″ mains, the diggers are placed twelve feet apart, for 20″ and 24″, eight feet apart, and for

Fig. 8.—Ditch Target.

30″, six feet apart. For 20″ and 24″, no trimming is done until the excavation has been completed. For 30″, at a depth of four feet, it is necessary to place one man on the bank to trim the material thrown out by every two diggers.

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On every job, special men, such as caulkers, or pipe layers, are assigned to open over the mains to which connection will be made, and over any places where obstructions are expected, the places above described, being those which may disclose conditions affecting the depth of the trench, and which therefore must be known before any bottoming can be done.

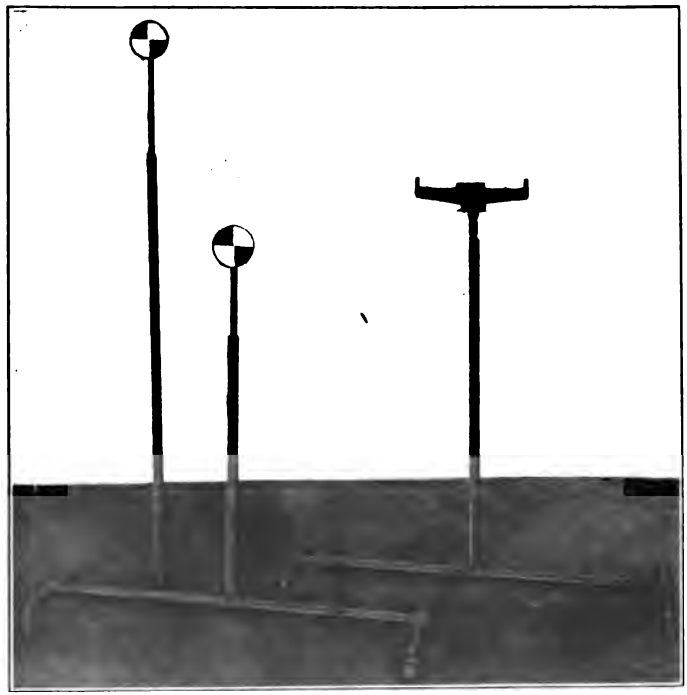

Fig. 9.—Ditch Target.

The considerations affecting the depth of a main do not fall within the scope of this paper. It suffices here to say that a cover of three feet may be regarded as standard.

After the depth of trench has been decided, the ditch targets, Fig. 8 or Fig. 9, are placed in position.

When working in frozen ground, one or more holes should

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be made through the frost, and then by using the frost wedges, C, Fig. 10, and barring off from the face thus made, the frozen ground can be lifted off much as would be a concrete base.

ROCK EXCAVATION.

Where blasting is not necessary, as the rock may be removed by bars, A, Fig. 10, wedges, D, Fig. 10, and sledges, B, Fig. 10, the men work in pairs in a section so as to give each other assistance. The small spalls are thrown with the dirt on the opposite side of the trench from the large stone.

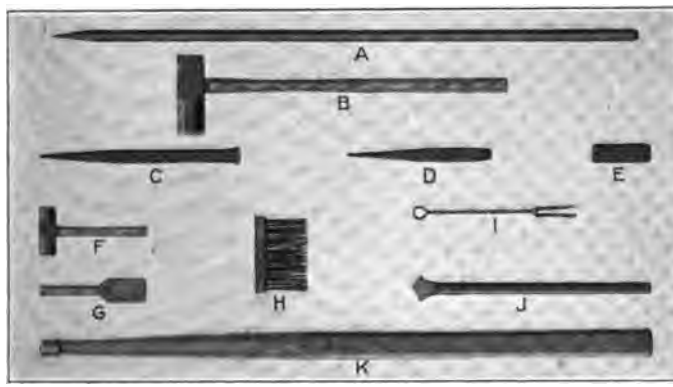

Fig. 10.—(A) Bar for Removing Rock. (B) Sledge for Removing Rock. (C) Frost Wedge. (D) Wedge for Removing Rock. (E) Bursting Wedge. (F) Caulking Hammer. (G) Cement Caulking Tool. (H) Wire Brush for Cleaning Cast Iron Pipe. (I) Bag Fork. (J) Drill Used in Blasting. (K) Porter.

Where blasting is required, three men form a gang, and the gangs work as close together as possible. One man holds the drill, J, Fig. 10, and two men strike. The charging, covering and firing of the holes should be delegated to one man, who should be an experienced rock man. Upon this man's judgment will depend the placing of the holes and the charge used. In general, the attempt is always to secure a face extending the full depth of the proposed trench. By staggering the holes in the various rows, the best progress is made. Where the rock

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is very hard on small mains, it is advisable to start with a width of trench twice that required for earth. This will allow for failure to blow out to complete width in places. Often, of course, the trench will widen still more from blowing.

All firing should be done from a battery. Great care must be taken to be sure that all workmen and the public are at a safe distance before firing.

There should be a space of at least 4" between any solid rock left in the trench and the nearest point of the main as it rests on its blocking. This is necessary to minimize the chance of future breaks, or leaks, due to later blasting operations when laying other structures.

LAYING.

ORGANIZATION FOR, AND DETAILS OF, PIPE LAYING.

LARGE MAINS.

The trench having been excavated, as previously described, is now ready for the pipe laying gang. Before telling of their work, the complete organization for laying 20" and larger mains will be here given as follows:

One trenching foreman and eighteen men
One laying foreman and twelve men
One back-filling foreman and eight men

Better results are obtained by having one foreman over every separate gang, than are possible by attempting to work with only one foreman. If the general main foreman is not on the work frequently, authority in his absence should rest in one of the foremen, probably the laying foreman. The laying gang, if working steadily, would require more diggers and backfillers, but in practice, obstacles arise to interfere with laying, and therefore the laying gang is always used more or less to aid the other gangs.

The laying gang contains four caulkers, or joint makers, and eight pipe-men. As far as possible, the various routine

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duties that arise should be definitely assigned to individual men, so that as the work progresses there is no confusion and each man becomes adept at his special lines of work. The foreman lays out the bell holes and starts his gang on them, also borrowing laborers from the trenching gang if necessary. Each bell hole extends from three feet in front of, to one foot back of the bell, clear across the bottom of the trench. Its bottom is four inches below the regular trench bottom, and its width, as measured along its bottom, is twenty inches greater than the trench width, tapering off to, and reaching, the trench width, fifteen inches above the proposed location of the pipe top. The material thrown out from the bell holes should be trimmed back, and there should be a two foot passage-way on the street on each side of the trench, before laying starts.

A dozen or more bell holes being completed, blocking is placed in position on the trench bottom. The "back" block is put with its near edge one foot back of the face of the bell, while the "front" block lies with its near edge three feet in front of the face of the bell. Back-filling will be reduced and the cavity under the centre of the pipe lessened if the trench has been so dug that the blocks may be set in the trench bottom so their tops will not clear it much more than one inch. This condition is difficult to obtain, however, and where there is insetting, care is necessary to ensure that the block rests on a flat surface, and not a concave one. The back blocks are set by spanning from one set to another with a level board set for the determined grade of the main. Or, each back block may be set by using a target. The front block is always set a little lower than the back block so that the main will just clear it.

The pipe which has been previously cleaned on the inside, and all dirt and scale carefully removed from the inside of the bell and the outside of the spigot end by a wire brush, H, Fig. 10, is rolled in position on the skids spanning the trench. The derrick, Fig. 12 is so placed that it will lower the pipe into the position desired. When moving the derrick, one man is at each of the rear legs and two men at each of the front legs.

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(The front side is considered as the side on which the winch is located.) When in position and in use, the four men on the

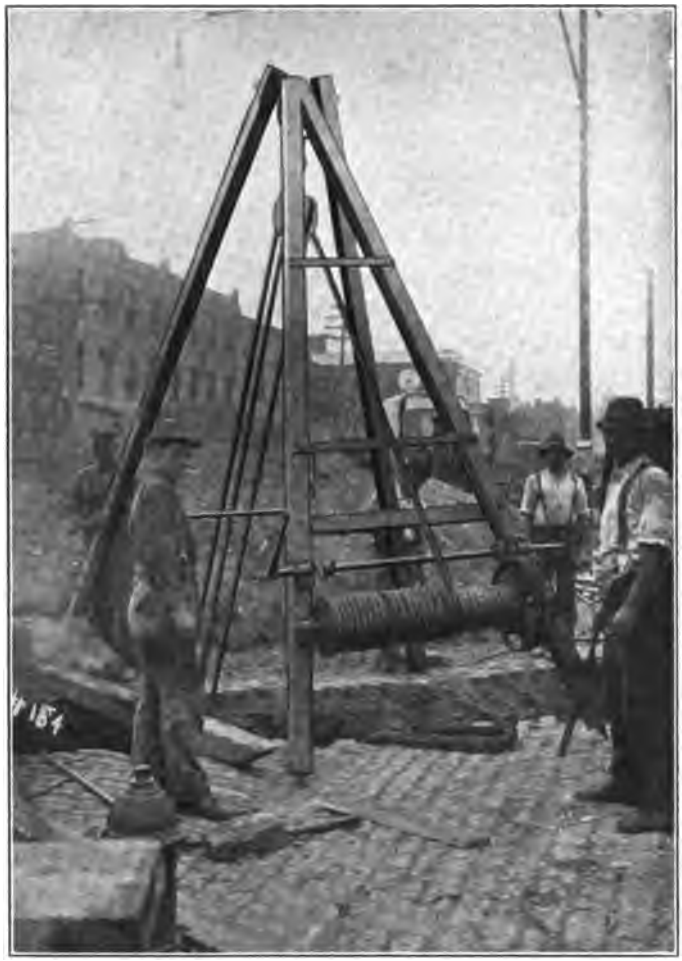

Fig. 12.– Derrick.

front side remain, but the two men at the rear legs are available for other work. The sling is adjusted so that the spigot

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end will be slightly heavier than the bell. The pipe is raised until the bell end clears the front skid, which is removed by the proper man while another man bears his weight on the bell, thus causing the spigot end to clear the rear skid. This in turn is removed and the pipe lowered. If, because of obstruction, the pipe cannot be lowered at the point where it is to be laid, then it must be moved along the bottom of the trench by successive shifting of the derrick, or if the use of the derrick is not possible, the pipe is lowered upon a timber truck and rolled into position over a board platform laid on the trench bottom.

While the pipe is being lowered, there are two pipe men in the trench, one in front of the bell end of the length being lowered, and one just back of bell end of the last length laid, into which he guides the spigot end of the descending length, aided by the other man, who grasps its bell end. When the bell of the descending length is from a foot to eighteen inches above the blocking, and its spigot end has entered the bell end of the last length laid, the man on the derrick brake releases the latter and the length falls free. This causes it to strike the blocking with sufficient force to firmly bed the latter. The length is once more raised by the derrick to just clear the blocking, and is then pushed home with a bar by the man at its bell end. The foreman in the meantime has gotten into position to sight along the line, and if the length is in line, he gives the signal to lower. If not, he indicates the shifting required before lowering.

The length is prevented from getting out of line by the insertion of blocks and wedges between the pipe and each side of the trench, several feet back of the bell. These blocks are not removed until the earth has been refilled around the pipe along four or five feet at the centre of the length. In the case of cement joints, this refilling is always done before the joint is made, but in the case of lead joints, such partial refilling need not be done. Where the trench is at all unstable, this refilling is of great importance.

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While this blocking is being done, the men who removed the skids have placed them across the trench, in the proper position for the next length, and rolled this length upon the skids in position for lowering, and are ready to assist in moving the derrick to the new position. From this point, the sequence of operations already described, is repeated.

As soon as the length is wedged in position, two caulkers start to drive in wedges on the front block, *viz.*, the one under the spigot end of the length just laid, and raise this spigot end until it is central in the bell end of the length last laid. The joint is then yarned. At this time, wedges may be driven on the back block, care being taken not to raise the length off this block.

In laying pipe, it is often necessary to remove shoring. This work is done by the pipe laying gang, and may require the especial attention of the foreman to prevent too many shores being out at any one time, or too great delay in replacing shores, for carelessness in these matters may involve damage to both work and workmen.

SMALL MAINS.

For small mains, under the ordinary city conditions, where each job is only one or two blocks in length, the entire main gang will not exceed eighteen men, and will include two caulkers and four pipe men.

After the trench has been completed, or nearly so, and any special work of connecting to existing mains finished, the caulkers and pipe men are started on the bell holes. Each bell hole should extend from eighteen inches in front of the bell to the back of the bell, should have a clearance of six inches under the pipe and of fifteen inches on each side. Back of the bell hole, a notch is cut in the bottom of the trench for the block, but care is taken to make the top of the block slightly above the trench surface.

While the pipe is being laid, two men are in the trench, one a caulker with a spirit level and a bundle of yarn strips, cut to the proper length, at the spigot end of the length to be laid, and

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the other a pipe man with a porter, K, Fig. 10, at the bell end. Three pipe-men are on the bank, and one inserts a porter in the spigot end of the length as it lies along side the trench, and lifts it. As it raises, a pipe man slides over the spigot end a loop of rope already made and resting against the end. He holds one end of the rope and passes the other end to a pipe man on the other side of the trench. The two men take up the slack on the rope, and then the man who raised the spigot end with the porter, goes to the bell end and pushes it off into the trench. The men holding the rope attached to the spigot end, prevent that end from dropping all the way to the bottom. The two ends of the rope are then taken by one of the two men, and he straddles the trench, while the man in the trench at the bell end raises this end with his porter. The length is thus suspended only a few inches above the trench bottom. The spigot end is caught by the caulker in the trench, who wraps a piece of yarn around it and enters it into the bell end of the length last laid. It is then pushed home by the man at the bell end. Now one end of the rope is dropped, and after entering the spigot end, the caulker pulls the rope from around the pipe and walks to the bell end. Here he places his level on the pipe to see whether there is the proper fall. If not, the proper level is obtained by varying the blocking, the pipe being raised by the pipe man in the trench, and the caulker inserting the block which is handed to him by the pipe man on the bank, who had held the rope.

In the meantime, the other two pipe men on the bank have gotten another length into position for lowering, with the rope under it, as described before. The second caulker is following along, driving in the yarn put in by the first caulker. When all the pipe has been laid, or when it is desired to begin making joints, the foreman straddles the trench at one end of the line, and lines up the length by the aid of two pipe men who walk along in the trench, each with a long bar, one on each side of the pipe.

The procedure above described will care for mains as large

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as 8". For 12" there is needed two more pipe men and another rope to be used at the bell end over a porter inserted in the bell. The rope at the spigot end will always require two men.

There will be instances where 16" pipe may be laid without a derrick, and in that case it will be treated just as 12" with the addition of two more men to the pipe laying gang.

CONNECTION WORK.

CLOSING GAPS.

The procedure followed in straight pipe laying has been pretty well covered, but some other necessary phases of main laying are still to be described. Every main laid is connected at one or both ends to existing mains, and often neither connection is made until the close of the work, and involves, therefore, the closing of a gap. Where 8" and smaller, this connection can be made by "folding in" instead of sleeving, if the trench is free enough of construction to permit whatever deflection from a straight line is required for the "fold." As far as possible, it should be known before laying is begun, in what way connection will be made to the existing main. If by folding, then a gap two inches more than the laying distance of two lengths should be left. This will make the folding a little easier, and by distributing the two inches over the three joints making up the fold, no one joint will be very far from home. In folding, the far ends of the two lengths forming the fold, are put home in the ends of the lines to be connected, and then the adjacent ends of the folding lengths raised by ropes, until spigot will enter bell, when they are lowered into line, and the joints, if necessary, equalized, as indicated by each of the bells concerned in the "fold," being equally far from the line marked on its engaging spigot. This line shows where the bell should come if the spigot is home, and should be marked on every spigot forming part of a fold, where there is over half an inch slack to be taken up per joint.

For pipe, 12" and larger, the use of a sleeve is usually preferable to folding. Much time has been lost through attempts to fold large pipe, in order to avoid the fancied disadvantages of

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a sleeve and to save one joint, and often all the time spent was lost and the sleeve resorted to after all, especially if the foreman tried to work without any slack. The use of a sleeve will enable a spigot piece to be used, and in large work, where a stock of old spigot pieces may be on hand, the gap left should be of the right length to use up one of these pieces without further cutting. Where a pipe must be cut for the gap, its length should be at least one inch less than the distance between the face of the bell and the end of the spigot to be joined. This is especially important in very large pipe where the cut may break out a little jagged, and where an attempt to make a cut piece just the distance between bell and spigot, is apt to result in a piece too long at various points, necessitating a tedious cutting off of these projections. Naturally, in using the cut piece, the more uneven end is put into the sleeve. Before the cut piece is lowered into the trench, the sleeve is placed over the spigot end of the gap, and on this end and also on the end of the cut piece to go in the sleeve, a line is marked seven inches back from the end. Then the cut piece is lowered and put home in the bell, the sleeve is slipped forward over the gap and placed so that each face is equidistant from the marked lines. Such a sleeve joint involves an air gap of at least an inch longer than the bell depth. Unless the sleeve used is provided with internal ridges to serve as a joint backing, this gap should be covered by sheet metal to prevent any chance of the yarn and lead, or cement, from either sleeve joint finding their way into the pipe.

CUTTING PIPE ON BANK.

The procedure in cutting pipe on the bank is as follows: The proper length is marked off from either end of the pipe at four points at least. If the measurement is made from a bell end, the necessary allowance must be made for the bell depth. The pipe is then rolled until a line has been drawn completely around it, through the marked points. Before cutting begins, it is placed on skids, one under the end farthest from the cut, and the other under the cut, and care

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taken to see that it stays there. No support at all should be placed under the short end. The skids should be as solidly placed, and as nearly level, as possible, in order that the pipe will not jar out of position during cutting. Each skid should be long enough to allow at least one and one-half revolutions of the pipe. For pipe, 12" and smaller, one man holds a dog chisel, one strikes with a fourteen pound sledge, or ten pound striking hammer, and a third rolls the pipe. For larger pipe, there are two men striking, and a man at each end of the pipe rolling it and keeping it in proper position. In every case, a continuous cut is made around the pipe, and is a comparatively light cut, not more than ⅛" deep. On the completion of this first cut, the cutting continues around the pipe as many times as may be necessary until the pipe breaks. With proper care, a clean cut will always be made. If for any reason the pipe breaks off irregularly, and the result is one or more places two inches shorter than desired, another cut will probably be required, unless the irregular end can form part of a deep sleeve joint. Any projection beyond the desired line can be cut off, but comparatively light blows must be used, to prevent cracking back of the line.

CONNECTING TO EXISTING MAIN.

At times the new main will be connected at the start to the existing system, and laying proceed without leaving any gap, gas being kept back by bagging. In such a case, it is, of course, imperative to do the connecting first. When a gap is left, however, the connection and any necessary alteration to the existing main need not be done at once, and as such alteration is usually harder than straight pipe laying, some foremen have a bad habit of putting it off till the end of the job. As a rule, expense will be saved by doing all the work necessary to close the gap except the actual closure, early in the job. It has already been noted under "Trenching," what an influence the connection to the existing main has on the bottoming of the trench.

In connecting to existing mains, the Philadelphia schedule is as follows:

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Schedule of Main Connections.

Size of New Mains	Size of Existing Mains									
	30" Hat Flange	24' Hat Flange	20" Hub Sleeve	16" Insert Branch	12" Insert Branch	8" Insert Branch	6" Insert Branch	4" Insert Branch	3" Insert Branch	2" Insert Branch
4"	"	"	"	"	"	"	"	"	"	"
6"	"	"	"	"	"	"	"	"	"	"
8"	"	"	"	"	"	"				
12"	Insert Branch	Insert Branch	Insert Branch	"	"					
16"	"	"	"	"						
20"	"	"	"							
24"	"	"								
30"	"									

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As is seen, the idea is to use a hat flange wherever the disparity between the connecting mains is very great, and the largest so large that a hub sleeve would involve heavy cost. As the disparity and the size of the largest main decrease, hub sleeves are used, and the ordinary branches. It is not always possible to follow the schedule strictly. Occasions arise where local conditions force the use of a hat flange, or hub sleeve, because of no room to insert a branch.

INSERTING BRANCH.

In mains below 12", the insertion of a branch is not attended with any special difficulties, but with large mains, the work requires considerable care, chiefly in regard to the cutting of the pipe and the bagging off of gas flow. The insertion of a branch will here be described without, however, any detailed description of bagging, as this will be taken up further on.

The location of the branch being determined, a sufficient length of the existing main is uncovered to afford room for bag holes on either side of the proposed cut, and it never pays to skimp in the question of the trench width either. Usually there is not much leeway in the branch location, but it is not advisable to cut a pipe nearer than one foot to any bell. By cutting a little from the spigot of the branch, and sometimes by reversing the branch end for end, a desired flexibility of dimensions may be obtained. When the exact location of the branch has been settled, then the two points of cutting are carefully marked on the existing main, and the pipe thoroughly cleaned at these points. The length of the piece to be cut out should be about one inch longer than the over all length of the branch. In determining the points for the cuts, the effect of the bell depth upon the location of the branch should not be overlooked.

After the line of the cut has been chalked on the pipe, if the latter is smaller than 12", then by means of a diamond point chisel, a cut at least ⅛" deep is made across the top semi-circumference. This cut is deepened by repeated going over with the diamond point until about half the thickness of metal

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is left. The whole cut is then gone over with a cold chisel, after which the chisel is placed in the cut at the top and driven into the pipe. It is then removed and a bursting wedge, E, Fig. 10, inserted and driven home until the pipe cracks completely around in the line of the cut. The same performance is repeated at the other cut, and the cold chisel is not driven into the pipe until both cuts are ready for such driving. In this way, after the pipe has cracked at the first cut, and is temporarily soaped up, there is nothing remaining to be done at the second cut except the driving of the cold chisel and of the bursting wedge. When the section has broken clear, it is hammered out of line, or perhaps it may be necessary to break a few pieces out of it to free it. Of course, before the cold chisel has been driven in, bags have been inserted to stop the gas flow.

Where the main to be cut is 12" or larger, the difficulty of making a crack already started in the cut follow around the uncut portion of the pipe increases very much with the size of the pipe, and in no class of main work is it more advisable to bear in mind the adage of "more haste, less speed," than in cutting large pipe in the trench. It will pay in the long run to cut just as large a proportion of the circumference (at least three-quarters) as can be gotten at. The cut is made in the same way as just described for small pipe. The cold chisel should be driven into the pipe not only at the top, but in several other places around the cut. Two bursting wedges should be used, and great care taken to see that they keep in the plane passing through the cut. Otherwise the wedge will not exert a pressure tending to crack the pipe along the cut, but there will be great danger that they will cause cracks to run into the main on either side of the cut. If the cutting has been properly done, the main will slowly crack all around the circumference as the wedges are driven in.

Where the pipe is 24" and larger, it is often advisable to make three cuts, the third cut being about one foot from one of the other cuts. When only two cuts are made, and the length

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of the pipe cut out is considerable, it sometimes happens that even after the section is cracked around the circumference at both cuts, it remains wedged in the line of main, and requires much work to get out. The reason for this is given in the next paragraph. Under these conditions, where there is a third cut, the bursting wedges are driven into it in such a way as to cause cracks each side of the cut, and to break off portions of the pipe. After that, it is comparatively easy to remove the first section, and then the rest of the cut out section.

In cutting a line laid with lead joints, the pressure brought to bear by the bursting wedges, seems sufficient to make the pipe take up at the joints adjacent to the cut, and thus the desired separation of the edges of the cut is obtained. With cement joints the strength of the joints is apparently too strong to be overcome, and so if the pipe being cut is under compression, or in other words, is at a higher temperature than when the joints were made, the desired separation at the cut will not be obtained by the wedges, and in that case it is necessary to cut around the entire circumference with diamond points and cold chisels, and dispense with bursting wedges entirely.

In every case, the pipe should be rigidly supported at each cut by blocking. Otherwise, there will be great danger of cracks being caused in the pipe on either side of the cut out section. If one of the cuts, say "A," comes back of a bell and nearer than a foot to it, and the other, say "B," in front of a bell, then it is advisable to force the wedges into "A" and sledge away the bell portion before driving the wedges into "B." This program tends to give a cleaner break at "B" than would otherwise be possible, but is only applicable when "A" is near a bell.

The process of inserting a branch after the section has been cut out, amounts to closing a sleeve gap, and has already been described.

PUTTING ON HUB SPLIT SLEEVE.

When the connection to the existing main is made by the use of a hub split sleeve, that portion of the pipe to be covered

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by the sleeve, is thoroughly cleaned, generally with foundry brushes. Then the two pieces of the sleeve are loosely bolted around the main, to see first whether the distance between outside of main and inside of sleeve is sufficient for jointing room, and second, to mark on the main the location of the circular cut. The sleeve is then removed and the pipe diamond pointed along the marked circle, beginning at the top. The cut is then gone over with a cold chisel, going into the pipe, except for two inches at the top, where a lip is left to hold in place the piece being cut out. A soaped wooden plug, of proper size to fill the opening in the main, is kept on hand for use in case the piece drops out unexpectedly.

A ring of some soft material, yarn, or wire covered with rubber hose is laid around the out side of the cut, and the sleeve placed in position on the main and pressing on the ring, which forms a more or less gas tight joint, and also prevents any jointing material from either end of the sleeve, getting into the pipe. The flanges of each half sleeve, if planed, are coated with white lead, but if rough, a layer of mill board softened in warm water, is placed between the two flanges. All of the above bolts are drawn up hand tight and then tightened by wrench, no two bolts on the same flange being tightened in succession, but the progress being from one end of the sleeve to the other, alternating from side to side.

In making up the joints at each end of the sleeve, if the latter is provided with internal ridges, the work is similar to any ordinary joint. If there are no ridges, care must be taken, if lead is being used, to be sure that the yarning is so well done that lead cannot get back past the yarn into the sleeve. If it does, a mispour may result. If cement is being used, where there are no ridges, yarn is introduced from one end for about four inches into the lower half of the sleeve. Then cement is put in from the other end of the sleeve until the yarn is reached. As the level of the cement rises, more yarn goes in, until finally the sleeve is filled from the far end. The joint is driven from that end, and then cement introduced

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at the other end to fill the four inch space. This cement is driven, and both the joints finished in the usual way.

The actual sequence of events is as follows: When the sleeve is bolted tight, a short piece of pipe, or a bend if necessary, is inserted in the hub of the sleeve. Then enough cement is put into the sleeve and the hub joint to make them gas tight. If a straight piece is in the hub outlet, a wooden plug is placed in the end of this piece. This piece is drilled to allow the passage of an iron rod, and with the latter the disc piece is knocked into the main. The rod is then withdrawn, the hole in the plug soaped up, and the sleeve and hub joints finished. If a bend is in the hub outlet, the former has been previously drilled by a hole so placed that a rod through it will knock out the disc piece. In the bend this hole, and in the straight piece a specially drilled hole, serves for a bag hole, when more pipe is laid.

PLACING HAT FLANGE.

In placing a hat flange, after cleaning the main at the desired position, the hat flange is tried for fit, it being desirable that there should be "iron to iron" contact with the pipe, especially at the bolt holes and around the edge of the opening. By covering the pipe with red lead and slightly moving the hat flange, the high points on the latter are indicated and chiselled off. When the hat flange is considered a sufficiently good fit, it is held in position, the mark made for the circular cut in the main, and the location of the tap bolt holes accurately centered by a punch provided with a bushing which just fits the bolt holes. Then the hat flange is removed, and the circular cut in the main made just as described for the hub sleeve. It is advisable to make this cut *before* the bolt holes are drilled, as otherwise there is danger of a crack occurring between the cut and a hole, under the influence of the constant hammering while cutting.

One of the upper bolt holes is now drilled and tapped, either by using the machinist rachet braced against the side of the

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ditch, or the regular tapping machine with a square shank drill. The "old man" or "dead man" is bolted in position over this hole, care being taken not to bring any part of it to bear on the disc that is to be removed. The arm of the "old man" can now be swung and fastened in any position so that each bolt hole can be drilled in succession and then tapped out, soap or clay being used to plug the holes as made.

The face of the flange is covered with white lead, over which a linen gasket, previously soaked in linseed oil, is placed, and the flange screwed down first hand tight, and then with a wrench, tightening in diagonal succession. Around each bolt is a piece of lamp wick. Of course, the material used between flange and pipe will vary with the individual using it. Mill board, canvas, lead, cement are all available. In general, the more nearly iron to iron the joint the better.

The details of inserting an outlet into the hub of the hat flange and of removing the disc from the main are exactly similar to those already described for the hub sleeve.

In placing hat flanges, a number of tools are needed which are seldom, if ever, used for any other kind of main work, and for this reason and also to ensure on hat flange work the presence of the necessary equipment, it is advisable to have this equipment contained in a special box, which is delivered on the work when required. The box is 8½" x 8½" x 2'7" long, and contains the following equipment:

1 "old man" and attachments
2 6" cold chisels
2 21/32" twist drills with taper shanks
1 12" flat file
2 gauges
1 4½ pound ball hammer
2 diamond points
1 centre punch
1 centre punch with bushing for centering
1 boiler ratchet with 11" handle
2 ¾" bolt taps with square shanks
1 single-head hexagon screw wrench

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JOINTS.

YARNING.

For pipe no larger than 16", one caulker only is needed to yarn a joint. The yarn is cut from 1½" to 2" longer than the outside circumference of the pipe, (and it is not good practice to use at any time, any length of yarn shorter than the outside circumference), as determined by taking one end of the yarn from the bale and passing it around the pipe. After a number of pieces have been measured in this way and cut from the bale, a sufficient number of strands are taken from these pieces, to make when twisted together, a rope large enough to fill solidly when compressed by the yarning iron, the radial space between spigot and bell. The proper number of strands for the size pipe being laid, having been determined and twisted together, one end of the rope so formed is tacked in the right hand side of the joint by the yarning iron and pushed at least half way in. The balance of the rope is then stretched around the pipe, being carefully kept in its twisted state, and driven back half way. This method of working, brings the caulker around to the right hand side where the yarn was entered first, and he continues around a second time, driving the yarn home this time. In thus making two circuits of the pipe in yarning the yarn remains at all times more nearly in a plane perpendicular to the axis of the pipe, and there is little danger of disturbing the lap.

Where cement joints are used, only enough depth of yarn is needed to support the weight of the spigot end and keep it central in the bell without any chance of sagging while the cement is setting. Any more than this amount is uselessly occupying space needed for requisite depth of cement. It is very important that the yarn be solidly driven. Also for cement joints, the front yarn is cut and prepared for the drivers, and laid across the pipe against the face of each bell when back yarn is driven, or at any time after the pipe is lined up. This method saves the drivers from carrying yarn from joint to joint, it renders uniform the number of strands used,

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not leaving this to the drivers' discretion, and it prevents dirt getting into the joint.

Where lead joints are used, the depth of yarn is determined by the depth of the bell, and of lead required. Each layer needed is put in as was the first, but a new starting point is taken, so that the lap of one layer does not come above that of a preceding layer. The most satisfactory way to determine when enough depth of yarn is in, is to measure back from the driving point on each yarning iron the depth of lead desired, and stop yarning when the point is touching the yarn and the mark is just hidden.

Mains 12" and larger, being blocked under the spigot end as well as the bell end, do not depend on the yarn to hold the spigot central in the bell, and, therefore, under these conditions, for cement joints only enough yarn is needed to prevent the cement getting inside the pipe. For mains over 16", two men are needed to yarn a joint. The yarn is inserted and driven just as described for the small mains, except that each man works alternately on his half of the joint until the yarn is completely back. Then both men drive at the same time until the yarn is properly compressed.

Jute yarn of a middling quality should be used, with fibers long enough to form strands that will twist properly. In this yarn a certain amount of oil will always be present, but careful buying will eliminate any bales with an excessive amount. Tarred yarn should be avoided, as the tar squeezes out under driving and deposits a film on the iron surfaces, which is detrimental to the tightness of lead or cement. For cement joints, some men use yarn soaked in grout, but the general preference is for dry yarn, both at the back of the bell and for driving, as it is considered advantageous to soak up some of the water squeezed out of the cement by driving. For lead wool, at first yarn with a slight amount of tar was used, as the tar was thought necessary to form a compact mass against which to drive the first lead wool strand. Experience

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has shown that the tar works through the lead wool and therefore dry yarn is preferable.

The exact weight of yarn required per joint will vary not only with the depth of yarn used, but also with the tightness of the driving. The schedules below represent New York practice with cast lead joints, and Philadelphia practice with cement joints:

New York City			Philadelphia	
Size of main inches	Depth of yarn inches	Weight of yarn ounces	Depth of back yarn inches	Weight of all yarn ounces
4	—	—	¾	6.0
6	2	2.0	¾	7.5
8	2	2.5	¾	9.0
10	2	3.0	—	—
12	2	3.5	¾	12.0
16	1¾	4.0	¾	17.0
20	1½	4.5	¾	21.5
24	2	5.0	—	—
30	2	6.5	¾	32.0
36	2	7.0	—	—
48	2½	8.0	—	—

LEAD JOINTS.

A discussion of the relative advantages of a lead, as compared with a cement, joint will be given when describing the latter joint.

Although depth of bells have been more or less standardized, there is much variation in the depths of lead used by different companies for the same sizes of pipe. Below is given the Philadelphia schedule for sizes to 30" inclusive, and the New York schedule for 36" and 48":

Size of Main.									
4″	6″	8″	12″	16″	20″	24″	30″	36″	48″
Depth of Lead.									
1½″	1¾″	2″	2¼″	2½″	2½″	2¾″	3″	3½″	3½″
Approximate Weight.									
6 lbs.	9 lbs.	12 lbs.	22 lbs.	36 lbs.	50 lbs.	62 lbs.	75 lbs.	124 lbs.	165 lbs.

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In considering any depths of lead, it should be remembered that the compression due to the most vigorous caulking does not extend deeper than about 7/8" below the surface of the joint.

While the pipe is being laid and yarned, one pipe man has been assigned the job of building a fire under the lead pot and having the lead hot when needed. He also brings the red clay

Fig. 13.—Rubber Band for Main.

used for the pouring gate to the proper consistency. The first step taken to pour a joint is when a pipe man puts on the rubber band, Fig. 13, being careful to drive it back closely against the face of the bell while tightening it. At the top, a pouring gate is made by the use of red clay, which is also smeared around the band where it touches the bell. The larger the pipe, the more important becomes all steps taken to

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ensure the tightness of the band and prevent any leaking of lead.

For mains as large as 16″, the man who put on the band also

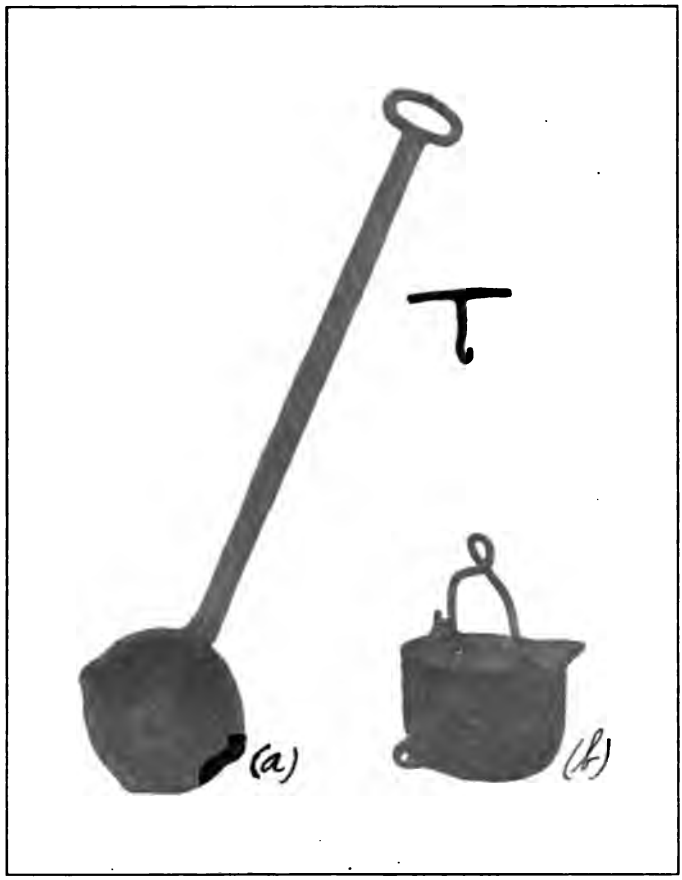

Fig. 14.—(A) Ladle for Mains 16″ and Smaller, (B) Pot for 16″ Main.

pours the joint. He receives the ladle, A, Fig. 14, (or the pot for 16″, B, Fig. 14) from the man in charge of the lead pot. For 20″ and larger, two men are required to carry the

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pouring pot from the lead furnace to the trench. One of these men lowers the pot with a rope and hook and holds the weight, while the man who put on the band takes a hook and pours the pot. The other man goes back to the lead pot, fills a hand ladle, and stands with it resting on the pot, ready to bring it quickly if needed.

On 30″ work, two men are assigned to place the band, and one of these men stands along side the pipe while the joint is being poured, with clay in hand ready to stop any leakage of lead. Where it is necessary to use more than one ladle, or pot, for a joint, the interval between pourings should be as short as possible. If for any reason a joint should not be fully run and the lack occurs in the upper half, the surface of the lacking portion may be roughened, a gate made around it and very hot lead poured. If the lower half of the joint is lacking, it will probably be better to cut out the joint and repour.

When the joint has been poured, a short interval is allowed for cooling, and then the band is removed and placed on the next bell. The joint is now ready for caulking, and for mains up to and including 16″, there is but one caulker to a joint. A caulker should drive five 6″ joints each hour, four 8″, three 10″ two and one-half 12″, or two 16″, the lineal inches of lead as measured on the circumference being about the same in each case. For 20″ and larger pipe, two men are required to a joint, and the awkward position in which some of their work must be done does not allow the results obtained on the small pipe, so that for two men, two 20″ joints, one and one-half 24″ or one 30″ will be about the hourly result.

In caulking, the tools shown in Fig. 15, are used. The joint is first chiseled all around between the lead and the spigot, being careful to see that no scale, or fillet of lead, is left against the iron. After the joint has been chiseled, except at the gate, the latter should be cut off, but far enough from the face of the bell to allow sufficient lead for caulking. After chiseling at the gate, the caulker begins with his smallest tool and en-

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circles the joint. He then repeats this performance with the next larger tool, and so on until he has used the largest tool possible for the size of pipe being laid. When this is done, the joint is completely faced, the lead will be driven about

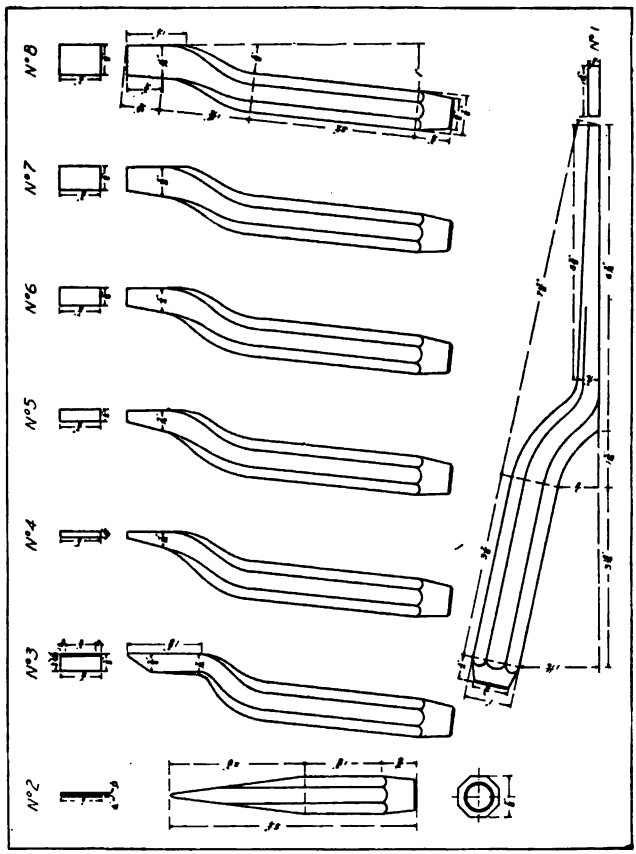

Fig. 15.—Tools Used in Caulking.

flush with the face of the bell, and the joint could in ordinary practice be considered finished. Some experiments made in Philadelphia in 1901 showed, however, so much greater resistance to strains brought to bear on joints by deflection and tension, when these joints had been caulked twice than when caulked only once in the usual way, that it is the Philadelphia

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practice to caulk all joints twice. In other words, after the joint has been caulked, as just described, each caulking tool is again used. Of course, this almost doubles the cost of caulking, which however, is not a large item in Philadelphia, due to the almost exclusive use of cement joints, as will be noted later on.

Each caulker should be provided with a steel stamp, containing a distinctive number or letter, and with this should stamp each joint made by him. This identification of work has a moral effect which is very favorable to good results, and enables the responsibility for a leaking joint to be placed against the original caulker.

The number of caulkers spoken of as forming part of main laying gangs, has been based on cement joints, and more will be required where lead joints are made, due to the longer time required for caulking lead, as compared with stuffing cement.

CEMENT JOINTS.

GENERAL.

The substitution of cement for lead as a jointing material for bell and spigot cast iron pipe is almost entirely a development of the last decade, but in that time many thousands of cement joints have been made with such favorable results on the score of tightness, and of economy in labor and material, as compared with lead, that the gas engineer using lead for mains under 20″ has the burden of proof against him. In Philadelphia, in the last thirteen years, 430 miles of cement joints have been laid, and in sizes under 30″ the number of leaking joints is about one to a mile.

For some time after the adoption of cement for most of the small main work in Philadelphia, lead was still used for small mains laid in the congested districts, and for all large mains. It was thought that as the tendency of 8″ or smaller pipe laid with cement was to break across the pipe rather than at the joint when under a stress, especially one due to construction, it was safer to use lead in all locations where other structures,

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especially conduits, abounded, as it seemed preferable under those conditions to have a number of small leaks in lead joints, than one leak which might quickly fill conduits and manholes with an explosive mixture. Cement joints have caused so few broken mains, however, that the tendency now is to use cement joints in all small mains except possibly when the cover is very small, so that stress caused by traffic or temperature is apt to be great, or when the renewal of a joint would prove very troublesome. One advantage of a lead joint is, of course, that if it leaks, simple recaulking will usually effect a cure, but the cement joint must be entirely cut out, and the conditions under which the joint must be remade are not as favorable for a tight joint, as if the pipe was being laid for the first time. Dirt is apt to get into the joint, and perfect adhesion may not be obtained with particles of the old cement left clinging to the pipe. It is also quite evident that if the space surrounding the defective joint is rather confined, the man cutting out the joint may suffer from the effects of gas. For all the above reasons, therefore, lead joints are preferable in all special locations where future joint trouble is expected.

To return to the history of Philadelphia's experience with cement joints, at first it was not believed that cement joints could be successfully made for pipe 20″ and larger. When this problem was solved, as will be described later on, and the practice of using cement joints on large mains was adopted, it was still thought necessary to put in a lead joint at intervals to provide for expansion and contraction. It was believed that the joint might prove stronger than the pipe, as is generally true for pipe 8″ and smaller, and therefore that under severe contraction a broken main might result. Naturally a broken 30″ main was not to be desired. Therefore in laying a line of 30″ and of 20″ in 1902, lead was used for every eighth joint. A comparison of the distance apart of two marked points on either side of a lead joint in the 30″ line, as between August and January, showed that the total movement could be accounted for by the contraction in only twenty-four feet of pipe.

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It is quite probable that the grip of the frozen ground against the pipe is much stronger than any stress due to temperature. In any event, as there were no cases of broken 30″ or 20″ mains, but only a few leaky cement joints, two facts were considered proven: First, that an expansion joint was of no use; second, that in a large main the joint was the weakest point. This last conclusion removed the final objection to using cement joint on large pipe. Ten years have shown a cement joint may leak after being tight for several years, and is then much more expensive to repair than a lead joint, but the saving in first cost is so great, especially in large mains, and the number of leaky joints so few, especially in small mains, that, as stated before, the user of the lead joints is put on the defensive.

It seems very probable that most cement joints leak not because of a temperature stress, but because of settlement of the pipe, and where a good foundation may not be secured, lead joints may prove cheaper in the long run. In this matter of settlement, it has been found advisable with pipe 24″ and larger, to let the pipe rest on the blocking at least over night, to allow time for the slight compression of the wood by the pipe that often occurs.

MATERIAL.

Undoubtedly Portland cement has been used almost exclusively for joint work, even in the early days when natural cement was so much cheaper. The material cost is, however, so small that few people felt justified in running the expensive risk of having leaking joints through using natural cement, generally comparing unfavorably with Portland cement in fineness and uniformity in composition. In Philadelphia, when starting cement joint work in 1899, the Dyckerhoff brand was used and proved generally satisfactory, except that at times there were complaints of lack of fineness. However, in 1903, American Portland cements began to challenge attention, and it was deemed advisable to test various brands to see whether one acceptable for cement work could

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not be found. Not only could price be saved, as compared with the Dyckerhoff, but also certain inconveniences inevitable in buying an imported article be avoided. As a result of these tests, Philadelphia has been using American brands since 1903.

Each brand was tested:

First, for solidity under driving. This test consisted in noting whether the cement seemed to rock, *i. e.*, act more or less like quicksand when being driven. It is quite desirable, in driving a joint, that the cement will not rock, but will stay where put, so that in driving cement home at one part of the joint there will be no lateral displacement resulting in the cement rising up at other parts of the joint.

Second, for activity. A very quick setting cement would be objectionable, especially for large mains where the joints take some time to make.

Third, for soundness. The soundness was tested in several ways. Freedom from checking or cracking was determined by a standard pat test. Expansion was judged by pouring grout into some bottles, and ramming stiff cement into other bottles, and noting which bottles broke after setting. Where expansion is not due to impunities, it is an advantage for joint makers. Into some of the bottles red ink was poured on top of the cement. If any contraction occurred, the ink would find its way between the cement and the glass.

Fourth, for fineness. This is a standard test and was made with a No. 80 sieve.

Fifth, for adhesion. In this test a split sleeve was clamped around a pipe and by using grease on one-half of the pipe, a joint was obtained between the pipe and one piece of the sleeve only. Weights were suspended from this piece until it broke away from the pipe. The strength of a cement joint under ordinary conditions is measured by the adhesion of the cement to the iron under a strain acting parallel to the axis of the pipe.

MAKING.

The pipe having been yarned, and well secured from any possible movement, by blocking beneath it and by refilled earth

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for three or four feet along the middle of each length, is now ready for the joint making process. On small mains the joint gang consists of one mixer, one passer, one packer and two drivers. The mixer has an iron wheelbarrow, a large pan, or a cement mixing board, measures for cement and water, and a small short handle hoe. The passer has a trowel and a pan, or a mixing board. The passer and packer wear rubber gauntlet gloves. The drivers have a caulking hammer, F, Fig. 10, and a cement caulking tool, G, Fig. 10.

The surface of the bell and of the spigot included in the joint have, before the pipe is laid, been very carefully cleaned. For this purpose a wire brush, and perhaps gasoline, has been used at least a day before joint making, in order to give the gasoline time to evaporate.

The mixer measures out a definite amount of cement and water, and mixes it into a thoroughly homogeneous mass. This mixing should be done in the shade if possible. There will always be more or less difference of opinion as to the exact quantity of water to use, some men preferring wetter cement than others, but in Philadelphia, the proportion recommended is three of cement to one of water by volume. This will make a mixture which will appear crumbly in the pan, and will just retain the impression of the fingers when squeezed in the hand. No more should be mixed in any one batch than can be used in the time before setting begins. This time will depend on the quickness in setting of the cement being used, as shown by the activity tests. Ordinarily, twenty minutes is the maximum time that should elapse from the mixing of water with the cement to the final work on any joint on which that particular batch of cement was used. The mixing pan, or board, should be kept scraped clean of all old cement. In practice, of course, it is hard to ensure that the mixer will always follow these rules relating to small and fresh batches, but the larger the pipe, the more certain it is that carelessness in these matters will mean leaky joints.

A batch being ready, the passer cuts from it with his trowel

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a wedge-shaped piece and hands this to the packer, who is astraddle of the joint. The packer takes the cement from the trowel in his gloved hands and starts to pack the joint from the bottom. He works up both sides together, finishing at the top, using the sides of his hands and fingers to push in the

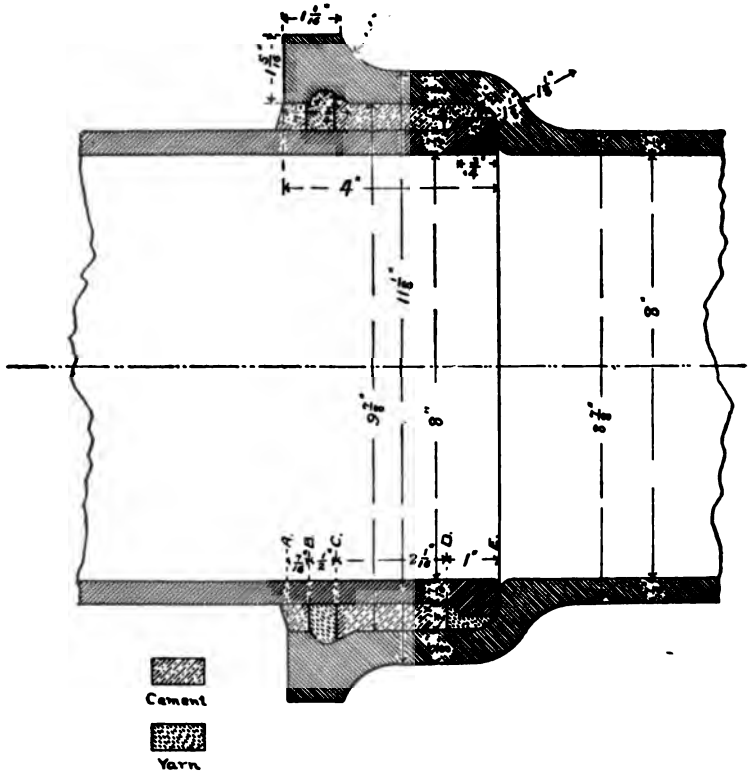

Fig. 16.—Cement Joint.

cement. He considers the joint to be fully packed, when on pushing his fingers on the lower half of the joint, the cement pushes out beyond the face of the bell at some point along the upper half. When this is the case, he starts from the bottom and coming up simultaneously on each side, wipes away with

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the finger tips of each hand, any cement on the spigot outside of the bell, and on the face of the bell itself. At this point in the process the cement occupies the whole space A-D, Fig. 16.

The driver now begins by taking up the yarn strands, already prepared for him, as described under "Yarning," and lying across the pipe. These he twists if necessary and tucks one end in on the left hand side of the joint near the top. He then starts to push the yarn in past the face of the bell, working down along the left hand side and up the right hand side to the starting point at the top. The yarn has then entered the bell all the way round, and the excess cement is scraped off by the caulking tool and drops to the bottom of the trench. Beginning at the first starting point, the driver now goes around the joint in the same direction as before, caulking the yarn until it feels solid under the caulking tool. The proper amount of driving to be done to a joint may not be described, but can be learned by experience only. It is quite possible to drive the yarn too hard. When the yarn begins to show moisture, this is a usual indication that enough driving has been done. The driving yarn then occupies the space B-C, and the cement the space C-D, Fig. 16.

After packing all the joints laid out for him, the packer starts at the beginning of the line, and fills the space A-B, Fig. 16 with cement, leaving a surface flush with the face of the bell as shown. This last fillet of cement serves merely to protect the driving yarn from the soil, not being gas tight itself. Rather wet cement of dough-like consistency is used, forty-five pounds being mixed at one time on 6″ work, enough to make twelve joints.

A gang of five experienced men following the procedure above described, can make fifty 6″ joints in an hour, or thirty-five 8″ joints, or twenty 12″ joints. For mains 16″ and larger, the gang is composed of one mixer, one passer, two packers and four drivers. The method of working is the same as for the small mains. Fourteen 16″, ten 20″, seven 24″ or five 30″

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joints represent what can be done per hour by these eight men when experienced.

TEMPERATURE PRECAUTIONS.

While the use of cement joints on small pipe dates back for many years, it is believed that only since 1902 have cement joints on large pipe been successfully made on an extensive scale. At that time the Philadelphia Gas Works determined to use cement on its large mains if possible, and after a few weeks of failure, involving the cutting and remaking of several scores of 20" joints, it was discovered that if the temperature of the main was kept nearly constant from the time the joint was stuffed until it had set, tight joints would be the rule and not the exception, even on 30" pipe. Also, in order to throw the least possible strain due to temperature changes, on the finished joint, it is advisable to have the temperature of the pipe as close as possible to mean underground conditions. This, of course, is more easily, or perhaps only attainable, when main laying occurs during the spring or fall months.

Therefore, it is the Philadelphia practice to give preference to these months for large main laying, and this is usually quite feasible because the need for such mains is seldom so imperative that a delay from winter till spring, or summer till fall, is not possible. Small mains, of course, have to be laid at all seasons of the year, but fortunately, a given range of temperature during joint-making and setting does not seem to have the same harmful effect on a small, as on a large, pipe. Indeed some people do not believe it is necessary to take any temperature precautions when laying pipe 8" and smaller, but such a course will often involve a risk out of proportion to the slight saving involved.

What are the temperature precautions to be taken? To begin with, if the pipe has been exposed to the rays of a hot sun long enough to become warm, joint making should not start until the iron has had a chance to cool to the air temperature. Ordinarily, pipe can be laid one day and joints made the next, in which case there is plenty of chance for the necessary

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cooling. If, however, joint-making must occur the same day, it may be necessary to use water on both bell and spigot ends just before laying, to bring down the temperature quickly. Neither bell nor spigot should be left wet, for such a condition would add undesirable moisture to the cement. It may also be necessary when the pipe, after being laid, is exposed to a hot sun before joint-making, and there will be no chance of its cooling through atmospheric changes, to sprinkle it with water applied at frequent intervals by a sprinkling can, or to adopt any of the precautions decribed later on as being taken after the joint is made.

The most acceptable time for joint-making on a sunny day is in the late afternoon or early morning. The pipe being at about the existing air temperature, and joints having been made at either of these times, the problem is to prevent a range over 10° in temperature for the time intervening between joint-making and testing. What this time should be will be discussed later. If the time is twelve hours, making in the afternoon is preferable, as the night range of air temperature will usually be less than the day range in the sun.

The earth that has been refilled midway around each length, not only helps to keep the pipe securely in position, but protects the covered portion from temperature changes, so that only about four feet each way from the joint remains to be protected. There are several ways of doing this. One method very effective, but comparatively expensive and hardly necessary except perhaps for 30″ pipe, is to place a few inches above the pipe a platform of loose boards, itself covered by six inches of earth. The dead air space thus formed acts as an efficient insulator, and in very hot weather it may be found advisable to build the platform after the pipe is laid, removing it for joint-making and replacing while the joint is setting. Following this procedure on a line of 30″ laid in May, air temperatures *under* the platform varied in forty-eight hours from 56° to 61° only, while the corresponding range of the outside air was from 53° to 74°. This record is typical of what is accomplished by temperature precautions.

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Another method of maintaining temperatures constant, which has proven quite acceptable under ordinary conditions, especially with pipe 20" and smaller, is to cover the exposed portion of the pipe with coarse bagging, kept wet by sprinkling. If the days are hot and the nights cold, it is a wise precaution to let the bags dry out towards dark, otherwise evaporation might bring about a pipe temperature lower than normal. Still a third method, applicable if the trench is through a smooth roadway surface and not for pipe larger than 20", is to stretch cheesecloth across the trench and by keeping this cloth wet, protect the trench from the sun's heat.

On cloudy days in spring or fall, often no precaution at all is necessary, and even sunny days at these seasons involve less air range between night and sun, than is true in summer. Severe winter conditions do not have to be considered because in such weather, no main laying is done, only repair work. In Philadelphia, cement joints are ordinarily used on this work, and resulting leaks, if any, have been few. The joints would be made as soon as the pipe was uncovered, and refilled right after making, so that ordinarily on winter work, the temperature of ground, pipe and air would not vary far from 30°, during the whole period from making to setting. In laying new pipe, it does not seem advisable to use cement joints when the air temperature falls much below 30°.

LEAD WOOL JOINTS.

Many slight modifications of the bell and spigot joints have been proposed from time to time, involving a change in the bell and spigot design, but have never met with any acceptance. In the last seven years, however, "lead wool," a special preparation of lead in a fibrous or shredded form, has been extensively used on mains 30" and larger. Especially notable is its use in New York City on 48" pipe. The fibers are put into the joint in the same way as yarn, one caulking tool being used until the face of the joint is reached, when sufficient tools are used to make a smooth face. The labor costs

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with hand caulking are, on large pipe, from three to four times as great as for cast lead. The material costs about twice as much per pound, but as less is used, the cost per joint is one and one-half times as much as cast lead. On long jobs of large mains, the use of pneumatic caulking tools has improved the work and lessened the cost, and an experiment is being made with a caulking machine, which will still further reduce the labor cost. However, the total joint cost will still exceed cast lead, and be so far above cement that, even though lead wool has almost a zero leak record, yet for pipe 24" or smaller, the argument seems to favor cement. On 30" pipe, cement shows more leaks than cast lead, and time alone will prove whether the leaks which may finally develop in cement joints in this size will outweigh the great saving in first cost. Above 30", the choice lies between cast lead and lead wool. On isolated work, such as leak repairs, where size of pipe or temperature conditions preclude cement, lead wool will generally prove more convenient and, through saving in time, more economical than cast lead.

A fuller treatment of lead wool joints is impossible, both for lack of space and of personal experience. The files of the gas journals for the last five years contain all that has been written on the subject.

TESTING JOINTS.

The ordinary small main, laid for low pressure distribution, needs no test for tightness prior to refilling, save a test with soap suds under gas pressure. The necessity for any test has a tendency to delay main work and increase expense, and this is especially true where the test is made by pumping air into the main. Experience has shown that the test with gas is sufficient under the conditions described. The suds are applied with an ordinary shaving or other suitable brush, over the face of the joint and the adjacent spigot and bell, and any leak in the joint will be indicated by the presence of soap bubbles. There will be times when it is advisable to refill as soon as the joint is made and to omit any testing whatever, as for instance

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where the trench cannot be kept open for any length of time, or when cement joints are used and temperature conditions are hard to maintain. In New York the success with lead wool joints has been so great that no test is made.

When the main is being laid by contract, or when it is larger than 12", it is good practice to make a test under air pressure of three to five pounds. Observations of a pressure gauge in connection with a soap-suds test of all joints, will indicate the degree of tightness secured. If possible, the test should be made at a time when the range of air temperature is small, for in a large main there might be a stationary or slightly rising pressure, even when there are a few large leaks. Of course, the possibility of this occurrence is greatly increased if the line under pressure is quite long, as is often the case where each successive section laid is joined to the preceding sections and air pressure applied to the whole line. Where each section is tested alone, and the length of line under pressure does not exceed one thousand feet, the gauge is more independent of temperature, but at the same time temperature must always be borne in mind. It is possible with falling temperature, to have a falling gauge on a perfectly tight line.

When any fall in pressure cannot be accounted for by temperature conditions and yet every joint shows tight, a search should be made for a cracked pipe. It is a very foolish act to pass a line, especially of large pipe, on a falling pressure until every inch of main has been carefully examined.

For any volume up to 2,000 feet of 30" pipe, the air pump, Fig. 17, is sufficiently large. For a larger volume, a steam driven pump could be used to advantage, unless the amount of use would not justify the outlay. Outfits are obtainable in which boiler and pump are mounted on a wagon frame, and so may be easily drawn from place to place.

Below follows a method used in Philadelphia for an air test. The test is usually made as near 7:00 A. M. as possible. The night before, all openings in the main are plugged up, the air pump is attached to the main, and the mercury gauge is

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examined and made ready for attachment. In attaching the air pump, a 1¼" hole is tapped either on the main or preferably, in the closing plug or cap. Sufficient 1¼" pipe provided with suitable fittings to allow a ⅜" connection with the gauge,

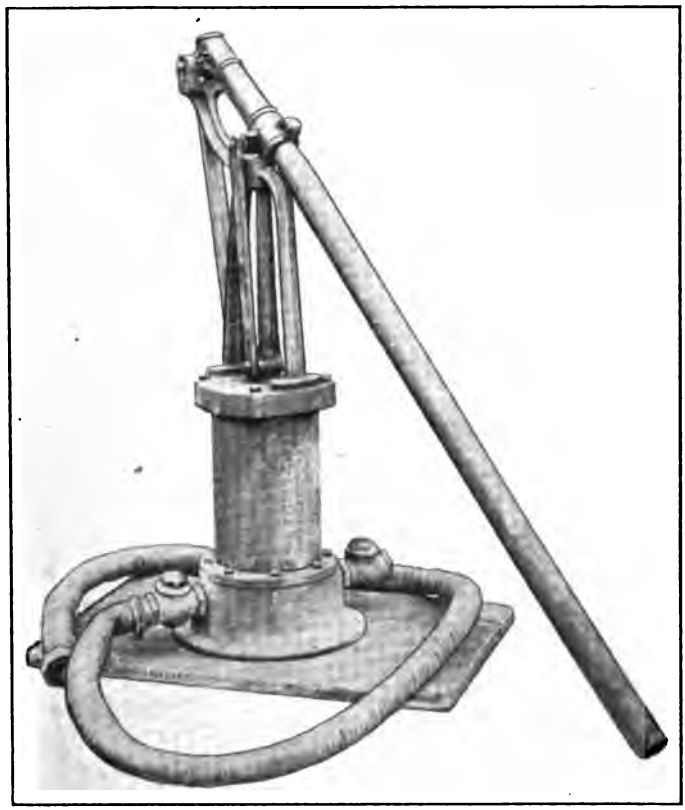

Fig. 17.—Air Pump.

is used to place the gauge in a convenient point for observation. Armored hose connects the 1¼" pipe to the pump.

Arrangements are made to commence pumping at such an hour in the morning that the required pressure will be reached at 7:00 A. M. With the pump shown in Fig. 17 for a pressure

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of three pounds in five hundred feet of 30", four men would be needed for two hours. The test is made by two men with pound brushes and a bucket of ivory soap suds. A foreman supervises the work and marks any leaks as found. When the test is completed, the pressure should be relieved through the standpipe or in any other way, before removing the plug or cap at the end of the section under pressure, as, if not, there is danger of injury to the workmen.

PRECAUTIONS AGAINST SETTLEMENT.

After a pipe is laid and covered up in a tight condition, the only reasons to cause breaks or leaky joints are some agencies, usually human, acting during subsequent exposure of the pipe; stresses due to street traffic and to temperature; and settlement of the pipe itself. The first danger must be guarded against by efficient line walking, the second and third are affected by the depth of the pipe, and the fourth, to which is due many leaky joints in all sizes of pipe and many breaks in small pipe, will be considered now.

Supposing, as is generally true, that the trench is in firm ground, the theory used to be that the pipe should be laid on this firm trench bottom, proper excavation being made for each bell. This theory worked all right in practice where obstructions were few, and therefore no occasion arose to decrease the expected cover of the pipe after the trench was bottomed; and, more important still, where the gang was small in number and contained one or more laborers skilled in making a bottom that lay in one plane, and was not formed of a series of small planes. The above conditions were never obtainable in towns of any size, and usually the result of laying directly on the earth was a line supported at a series of points along each length, and occasionally resting on refilled earth where the original trench depth was too great. Trouble has frequently resulted from such conditions, and, of course, more often with large pipe, with resulting heavy repair cost.

A little reflection will show that without any earth com-

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pression, the support of a length lying on the earth, is a line about eleven feet long. If, as would be usually done, the pipe was allowed to drop on its bed several times, then *assuming* it always fell in the same place, there would be a concave bed probably several inches wide. Actually, however, it would be impossible to get any greater bed than one dropping would accomplish, and if such dropping did not leave the pipe in a straight line with the pipe already laid, a crook must be left in the line, or the bed disturbed.

The use of blocking obviates the difficulties above mentioned. The trench need not be carefully bottomed except where the blocking rests. In setting the block, paving rammer should be used to ensure that the block has a firm bearing over its whole area. Another good way of bedding the block is to raise the bell end of pipe about two feet, and then allow the latter to fall free on the block. The pipe can now be freely moved sideways on the block, or up and down by inserting distance pieces and wedges, with the certainty that its stability is not being affected. The use of wedges and of the distance pieces of 1″ board enables an exact alignment as to height, something impossible to obtain when laying on the trench bottom.

In deciding on the sizes of blocking to be used for various sized mains, there is ample opportunity for the use of individual judgment. Below is the schedule used in Philadelphia:

SCHEDULE OF BLOCKING.

Size of mains	Size of blocking.			Size of distance pieces.			Size of wedges		
	Thickness	Width	Length	Thickness	Width	Length	Thickness	Width	Length
3″ to 8″	3″	12″	12″	1″	12″	12″	1½″	4″	6″
10″ to 12″	3″	12″	18″	1″	12″	12″	2″	5″	8″
16″ to 20″	3″	12″	24″	1″	12″	24″	3″	5″	12″
24″ to 30″	4″	12″	30″	1″	12″	24″	3″	5″	12″

For services use 2″ x 8″—8″.

The blocking must always be used of full width and placed upon undisturbed earth. For mains over 16″, two blocks are laid side by side at each blocking point, making the width of four blocks for each length.

This schedule may be considered by some as being too

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liberal, but it was designed with the knowledge that a few leaking joints under asphalt would pay for many feet of lumber. Two inch blocks undoubtedly could be used for small pipe, but 3″ will last longer, and the extra thickness may be needed some day to prevent settlement, where a block has been improperly imbedded. The blocks have been made short and wide rather than long and narrow, because the more nearly square the block is, the more apt is it to bear on its whole surface. A block which is almost as long as the trench is wide, will require great vigilance on the foreman's part to prevent many such blocks being set, resting on earth only at each end.

The surface area of the blocking for each size main as given, causes a pressure per square inch of such surface, which is the bearing surface of the blocking on the trench, varying from thirty-two pounds in the case of 8″, to ten pounds for the 24″, the weight taken being that of a pipe itself and a parallelopipedon of earth, three feet high, twelve feet long and of width equal to the outside diameter of the pipe. For pipe over 8″ in size, there are two blocking places in each length, and this enables a positive support to the spigot end, which is of great advantage in making cement joints, as it enables less yarn and more cement to be used, and prevents any settling of the spigot with a consequent leak. Where more blocking area is needed than will be given by two blocks to a length, four are used, two at each blocking place. In this way, 3″ x 12″ lumber can be used for all blocking, the only difference between the various blocks being in their length, and these latter have been so arranged that some of the larger blocks may be cut to form two smaller blocks.

There is only one objection worth noting to the use of blocking. This is the space left between the main and the trench bottom. The question of refilling this space will be considered later. As already stated, a little care in insetting the blocking in the trench bottom will reduce the space to rather less than one inch in height, and this care should be exercised especially with larger mains.

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Blocking will care for the ordinary conditions of main laying. Where the soil is of uncertain stability, or the weight exceptional, as with some special castings, especial methods might be used. Short piles may be driven into the trench bottom at each side and the blocking rest on them. Concrete or brick piers may be built. Such piers are often advisable under specials, particularly bends used where the main changes in cover, and a big pile of blocking would otherwise be required. In every case, however, the pipe itself should rest on wood and not on the pier direct.

BAGGING.

NECESSITY FOR BAGGING.

No matter how small the pipe, no connection should be made to a main either by a cut out or by removing a plug or cap, without first stopping off the flow of gas. There are many workmen and some foremen who object to this precaution in the case of 2″, 3″ or even 4″ mains, and who, if left to their own devices, would often "jump in" a connection without stopping off the flow of gas. Such a practice, however, should not be tolerated, as it involves too much risk to the workmen, and also to the maintenance of gas supply on the main concerned.

In the old days of small mains, animal bladders served fairly well, and there was nothing better until the advent of rubber bags, which in turn, within the last decade, have been largely supplanted by stoppers.

Of course, the larger the main, the more dangerous would be the result of unrestricted flow, and, therefore, the more care that is necessary in the provisions for stopping off this flow. In Philadelphia, one bag or stopper must be used to prevent gas flow in mains 8″ and smaller, and two bags, or two stoppers, or one bag and one stopper, for larger mains. The last combination is to be preferred, especially in the very large mains, where the stopper is not apt to fit close enough to prevent a leak sufficiently large to bother the workmen. Ordinarily, a

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separate hole is tapped for each bag, or stopper, and the latter is placed farthest from the opening, in other words, towards the gas flow, and takes up the pressure, so that the bag simply prevents what little gas may be going past the stopper, from getting into the portion of main being connected. This is on the assumption that a wrought iron "bleeder" pipe varying in size from 1" to 2" is inserted into the tap hole for the bag, and that through this pipe there escapes into the air, well above the top of the trench, any gas leaking past the stopper. There may often be cases when a bleeder pipe is not necessary. If so, of course the bag stands the full pressure differences, but the first stopper is the safeguard against any great gas flow, in case the bag should break.

SIZE OF BAG HOLES.

The schedule in use in Philadelphia, governing the sizes of holes to be tapped for the insertion of bags and stoppers, is as follows:

Size of main	Hole for bag	Hole for stopper
3″	1″	1″
4″	1″	1¼″
6″	1½″	1½″
8″	2″	2″
10″	2″	2″
12″	2½″	2½″
16″	*3″	3″
20″	*3″	3″
24″	4″	4″
30″	4″	4″
36″	4″	4″

*4″ will be needed for the heavy canvas bags.

INSERTION AND WITHDRAWAL.

In inserting a bag, the procedure is about as follows: After the hole has been drilled, the portion of the main where the bag will rest, is carefully cleaned of any metal cuttings, or any condensation, the latter often having a very rapid action in dissolving rubber. This cleaning is accomplished by means of waste or cloth at the end of a stick. Where condensation is

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encountered it is advisable by soaping to protect the bag as well as may be. Soap will also help in making a bag hold back gas where the inside of a main is quite rough. If it is thought desirable to use a bag saving device, this is now screwed on.

The bag fork, I, Fig. 10, is sometimes used in inserting the bag, which is placed in a folded position on the face of the fork, and the bag stem pulled back between the prongs near the hilt. The bag and fork are then entered simultaneously, the fork serving to force the bag down into the main and away from the hole. After inflation of the bag, the fork is withdrawn. Where there is much more pressure on one side of a bag than another, the fork is of special use in holding the bag in place until inflated. In the absence of a bag fork, a stick is used to force in the bag, which is always snugly rolled or folded.

A bag is properly placed when the axis, passing through the stem, coincides with the axis of the main. In inflating large bags, a bag pump, B, Fig. 18, is generally used. By means of a small bag inserted in the supply line, an indication is given of the degree of inflation of the bag in the main. This also can be told by observing the bag itself through the bag hole. Large bags have cocks attached to their stems to control the air flow. The stems of small bags are tied together in a kinked position. A small stick should be attached to the stems of all bags in such a way as to prevent the bag from being forced away from the bag hole. All bags or stoppers, while in use, should be under constant supervision to ensure that they are maintaining their inflation and position.

In removing a bag, the air is first allowed to escape, and then the bag is slowly pulled out through the opening, first, by means of the neck, and then by pulling on the bag itself, the pull being always applied close to the main, and the bag kept rolled up like an umbrella. All condensation should be immediately removed from the bag by the use of soap and warm water.

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In inserting a stopper, A, Fig. 18, it is neatly folded and pressed together, and pushed in carefully and slowly, it, as well as the bag, being always a snug fit in the hole allowed by the schedule. The handles are kept uppermost until the stopper is completely within the main. The stopper is now revolved through 180° and pushed into the hole about as far as it will go, bringing the top of the flexible frame a few inches

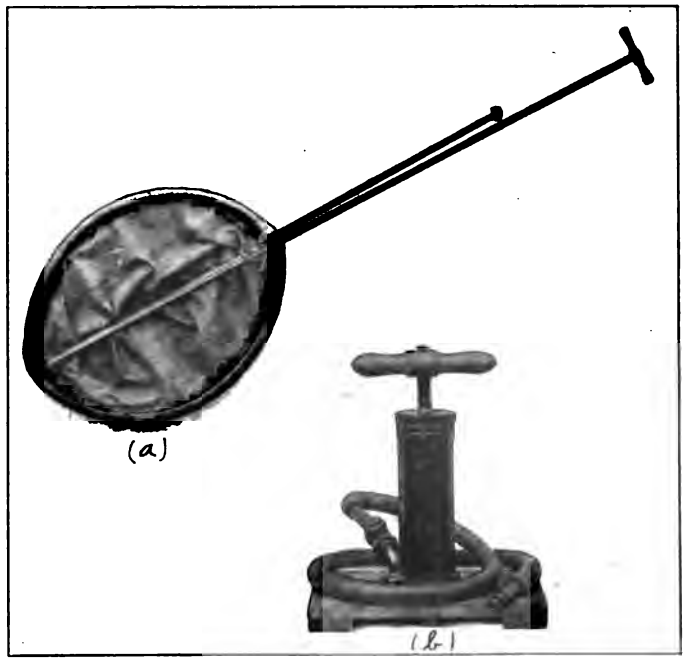

Fig. 18.—(A) Stopper. (B) Bag Pump.

from the hole. The top of the flexible frame is then in contact with the top of the main, and a short distance in front of the hole, the bottom of the frame is on the bottom of the main, and the axis of the stopper is at an angle of about 45°, with the axis of the main. The top is kept in this position, or perhaps forced slightly away from the hole by means

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of the short handle, while by the long handle the lower end is drawn back towards the hole, thus bringing the plane of the frame into perpendicularity with the axis of the main, and forcing the frame into a circular shape. When ready to draw the stopper, the lower end is pushed forward along the bottom of the main, and the upper end is drawn slightly back, until the frame has assumed its greatest possible length. The stopper is then revolved 180° bringing the frame on top, and withdrawn.

CARE IN REGARD TO SUPPLY OF GAS.

Bagging off the supply of gas involves certain operations which, unless precautions are taken, may result in a diminution, or entire stoppage, of supply to consumers. These operations are: First, the tapping of the bag hole and any subsequent opening of it, allowing free gas flow; and second, the insertion of the bag with a consequent interruption of gas flow in the main.

The precautions to be observed in connection with the tapping of the bag hole, of course, apply equally to the tapping of any hole for any purpose, or to any work which makes in any pipe conveying gas, an opening whose area is of appreciable size as compared with the area of the pipe. Experience has shown that if flow is quickly established through the ordinary hole tapped in the average size main, the diminution in pressure caused thereby, may be quite sufficient to put out lights turned low, and that the quick uncovering of the opening, causes the pressure in the main to fall momentarily to a point lower than is caused by the steady flow of gas through the opening. Of course, the amount of effect produced in any main, that is, the number of feet each side of the opening that the effect extends, and the extent of pressure lowering, depends entirely upon the relation between size of main and of opening, and the conditions affecting the supply of gas into the main. However, such serious results may ensue from unlighted gas issuing from burners, extinguished by a lowering of pressure, because of the careless tapping of holes and their uncovering in putting

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in bags, that it is wise, especially in cities and large towns, to observe the following precautions.

When any opening is made between a main and the atmosphere, so that gas may escape from the opening, the plug, tap, or fitting, the removal of which makes the opening, should not be moved away from the main at right angles to it, but should be moved sidewise over the opening, and kept in close contact with the main, and as it is moved off the opening, the fitting, or plug, which is to take its place, should be moved on. Neither motion should be rapid or sudden. The result will be that at no time is the whole area of the opening exposed for the escape of gas, and also that there is no rapid change in the area through which gas is escaping.

When a hole has been tapped for the insertion of a bag (or stopper) and the bag is to be inserted at once, in removing the tap from the main, it should be slid sidewise over the hole and followed immediately by the hand, placed in such a position as to partially encircle the receding tap, and to block off the escaping gas as far as possible. In inserting the bag, the hand should be moved slowly over the hole to afford room to insert the end of the bag, and the hand should continue to cover the hole as much as possible, until the latter is filled by the bag. As the bag gets further in and begins to taper off towards the top, the hand should again be placed over the hole, and kept there until the bag is inflated. In withdrawing the bag, the same precautions should be observed in reverse order; and, in general, everything done which will decrease the absolute rapidity of gas flow, and the rapidity of change in amount of flow.

The practice described above should be followed in mains of all sizes. In addition, where the main is 3″ or smaller, or is supplied from only one end, and any portion of this sole supply is 3″ or smaller, a pressure gauge, as shown in Fig. 19, should be connected with the main so that any pressure drop can be noticed, and, if at any time as little as 1.0″ pressure is shown, then an examination must be made in the neighbor-

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ing houses to make sure that no lights have been put out. In general, in any work involving possible interference with the evenness of gas flow, any nearby street lamp supplied from the main in question should be lighted, as its flame will be a valuable telltale of what is happening in the main.

Discussing now the second precaution, *viz.*, what will be the effect of the insertion of the bag in that portion of the main which must not be deprived of gas, the whole question hinges upon what is *known* of the main connections in the region in which the work is being done. Where the records are perfect, and show that a main is connected at both ends, then in the absence of a stoppage, such as water in a trap, or a drip, or some other obstruction, a bag, or bags, may be inserted with confidence that the result will be the stoppage of supply to that section of main only, whose isolation is desired.

If, however, it is necessary to bag off a portion of a main which is not positively known to be supplied from both ends, the work should be done according to the following directions, as illustrated by Fig. 19. Place a bag (or stopper) through the hole at "X" in the position "A," Fig. 1, judging the flow of gas toward the bag by noting the speed of the gas escaping from the bag hole. The escape of gas thus permitted should be brought on gradually for reasons already explained. If no drop in pressure is noticed, deflate the bag, inflate in position "B" and test for flow of gas as before. If this test indicates a satisfactory flow, leave bag in position "B." Another bag inserted through bag hole "Y" in position "C" completes the operation of isolating the portion of the main to be repaired or removed. The tests at "X" have demonstrated that gas was being supplied in both directions, and that therefore no by-pass is necessary.

If on making test with bag in position "A" or "B," a drop in pressure is noted, indicating some obstructions or a dead end, the bag should be left in position inflated until the extent of the section deprived of gas is ascertained and the meter cock in each house closed. (This same routine should be followed in

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any case of bagging off a main where it was discovered that gas had been shut off from a section not meant to be isolated). Having done this, the bag may be deflated and gas again allowed to flow into the section unintentionally isolated. Before resuming the work necessitating the bagging, a siphon gauge, Fig. 2, should be attached to the section previously isolated and a by-pass laid around the section to be bagged off. Observations of the gauge should be made while insert-

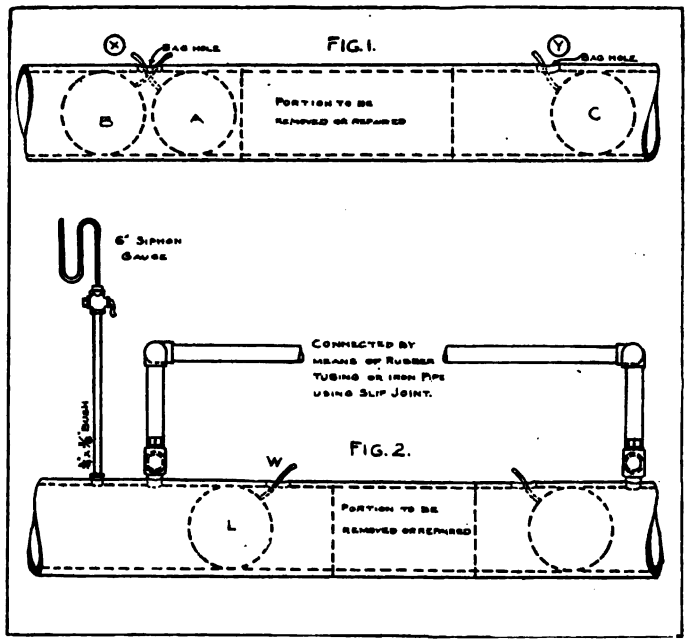

Fig. 19.—Pressure Gauge.

ing or removing by-pass, bags, etc. If at any time the pressure falls below 1.0", the gas should immediately be shut off the section so affected, and an examination made of each house as already described. Fig. 2 shows the position of the bags and by-pass when ready to cut out or repair under the conditions already described, in other words, the arrangement necessary when the main is fed from one end only.

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When withdrawing the bags in the arrangement as shown in Fig. 1, on completion of the work, the bag (or bags), which was the first to be inflated, should be drawn first, and the resulting pressure noted. In this way, if by any chance the supply of gas has been unknowingly cut off on the side of the section first bagged off, this fact will at once be shown on withdrawing the bag, by the entire absence of pressure, and the proper precautions can be taken. When, as in Fig. 2, a by-pass is in use and in place, the first bag inserted should be at "L" in the dead end supplied by the by-pass, being placed as shown on the side of the hole away from the section to be repaired or removed. This bag must be the last one withdrawn, for the full supply of the main, in addition to the by-pass, must be available to the dead end section as the last bag is being deflated, or otherwise the escape through the hole "W," even with every care exerted, might be sufficient to render the supply through the by-pass insufficient to keep up the pressure in the dead end section.

PURGING.

The operation of "purging," *i. e.*, filling a main with gas, may be either very easy or very difficult, according as there happens to be a small length of main, or an extensive system to be dealt with. In every case, however, care is needed to prevent any chance of ignition of the explosive mixture of gas and air issuing from the main being purged.

In its simplest form as applied to a stretch of ordinary size main, ending in a location where a little gas smell is not objectionable, purging consists of removing a screw plug from a hole tapped in the main at the end farthest from the source of supply, and allowing first the air and then the mixture of gas and air to blow into the atmosphere until either by smell, or by sampling the issuing gas, it is believed, or found, that all the air has been removed. The advisability of sampling increases with the size of the main, and with the chance of the mixture of gas and air being supplied to consumers before any

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other operations tend to produce a flow of gas through the main in question, and, therefore, to reduce the air to a negligible percentage.

The sampling may be accomplished by filling with the issuing gas a deflated rubber gas bag, and then removing the bag to a safe distance, inserting a pipe with a burner attached, in the stem of the bag, squeezing the bag and lighting the stream issuing through the burner. The color of the flame will indicate how nearly pure gas the bag contains.

With an increase in the size (and to some extent the length) of the main, will result an increased volume of gas and air to be discharged into the atmosphere, before purging is complete. This will often mean the advisability of a standpipe screwed into the outlet hole, and discharging above the heads of pedestrians. Also, as the period in which an explosive mixture exists, is longer, than with a small main, the use of wire gauze in the standpipe is a wise precaution. This gauze prevents any flame which might ignite at the standpipe end, from flashing back into the main.

In every case of purging, the precautions already spoken of under "Care in Regard to Supply of Gas," should be carefully observed. After the main is considered to be properly purged, the plugs of all drip standpipes should be removed, to allow the escape of any air that might be pocketed in the lower portions of the drip pots.

An arrangement that has been used in Philadelphia on mains 16" and over, is shown in Fig. 20. The convenient method for sampling the gas will be noted.

Very rarely it may happen that the main to be purged is situated where the escape of gas would create a considerable nuisance, as in a crowded business thoroughfare. If so, if it is not advisable to purge until the smell comes and then stop, trusting to the sufficient admixture of the air remaining with the gas, to prevent any chance of lights going out, or of very poor illumination, the only remaining course is to burn the

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issuing stream at the top of the standpipe. With a gauge of mesh as small as that used in safety lamps, and a standpipe equipped with four successive sheets of gauze, arranged in two

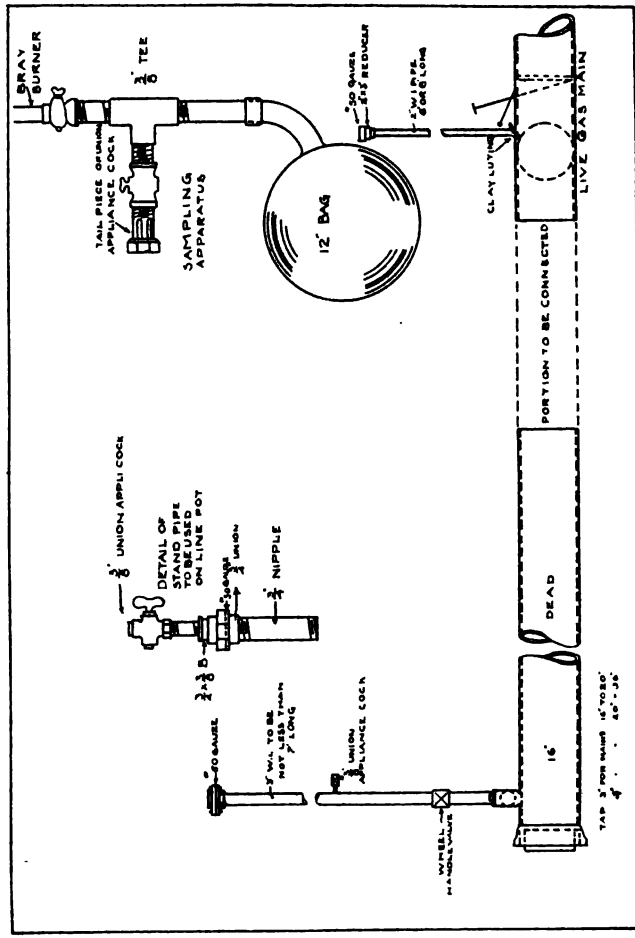

Fig. 20.—Method of Purging Large Mains.

pairs, two feet apart, each sheet of a pair being separated by a ½" gasket, there would seem to be no risk of any flashing back in the main, if care is taken to observe that the pipe is not becoming warm, for a reason now to be told.

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In supplying New York City with gas made on Long Island, it happened that fifty miles of mains were laid before the tunnel under the East River was completed. Therefore, this main system had to be purged more or less as a whole, and it was actually purged in two sections. It was decided to burn the gas in order to be sure that all of the air had been expelled. Standpipes with four gauzes about as described above, were successfully used on this occasion and also on each subsequent addition to the main system, until one day, when purging about one thousand feet of 20" main, an explosion occurred, due undoubtedly to the flame at the end of the standpipe flashing back into the main. The only explanation for the passage of the flame back through the four sheets of gauze, would seem to be that the flame first flashed back to the upper pair of gauzes, and burned above them so long as to make them red hot. In this case the flame would travel down to the second pair, and after they had become red hot, an explosion could occur if the mixture was still explosive. An observation of the temperature of the standpipe would have disclosed the fact of the flame burning on the gauzes, and the danger being incurred.

A feature of purging where more than a single line of main is in question, is the necessity for bagging at certain points to prevent large pockets of air. For instance, when one or more of the mains is fed from both ends, three bag holes, with a bag in the centre hole, will allow the air to come both ways to the bag, and issue out of the other two holes without forming any pocket. Naturally, in work of this kind, the tightness of the bags is very important, and each such bagging place should be under the continuous surveillance of a reliable workman.

MAINTENANCE OF GAS SUPPLY DURING MAIN LAYING.

IMPORTANCE OF MAINTAINING SUPPLY.

So far, in discussing the question of main laying, it has been assumed that the work involved an extension into new

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territory. Many mains are laid, however, to replace existing lines, and in these days of the extensive use of gas for heating and other domestic and industrial purposes, it is often imperative, with any due regard for the rights of the consumer, that any cessation in gas supply be as short as possible. This means to begin with, that gas supply be kept up either through the existing main or temporary main, until the new main has been purged. If gas is maintained in the existing main, but this must be disconnected from its ordinary source of supply, to allow the connection of the new main, then a by-pass must first be installed across the gap. It also means that the transfer of old service to new main, or from old main and old service to new main and new service, should be done expeditiously.

In considering this work, three different conditions will be taken up in turn: First, where the existing main is not in the way of the new one, and therefore can be kept in use until the main has been purged; second, where the existing main must be removed to make way for the new one, but prior to such removal a temporary main may be laid; and third, where the existing main must be removed, but no temporary main is feasible.

SUPPLY BY EXISTING MAIN.

Where the existing main, whether or not exposed in the trench made for the new main, may continue to supply gas until the new main has been purged, the work of main laying is not much more different than in the case of new extension, except for what support may have to be provided for any section of the existing main that may be exposed in the trench. At this point, it should be stated that the value of the iron recovered, even at scrap prices, generally makes it an economical proceeding, other considerations being equal, to lay the new main in such a location that the existing main may be removed with either no, or only a slight amount of additional excavation.

Before the new main is purged, all necessary service holes

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should be tapped, and service renewals made to within the cellar wall. Then in the case of a consumer whose service was renewed, the discontinuance of gas supply, will only cover the time necessary to transfer the piping on the inlet side of the meter, from the old service to the new one, which may involve only the unscrewing of the existing inlet connection, and the screwing of a new inlet connection attached to the new service. When the service does not need renewing, there will be necessary, in addition to the work inside the cellar and preceding it, the cutting of the existing service and its reconnection to the new main. The above service details apply equally as well to the paragraphs that follow.

SUPPLY BY TEMPORARY MAIN.

Where a temporary main is to be laid, its size should be determined from accurate knowledge of the maximum demand of the consumers to be supplied. Usually a 2″ or 3″ main will be amply large, and wrought iron is generally preferable for any size smaller than 8″. The location is normally above ground and close to the curb, either in roadway or on footway. Tees forming part of the line of pipe, make the best method of service connection. Each tee is joined by iron pipe, or by pipe and armored rubber hose to one of the existing services. This involves a cessation of gas supply while the service is being cut off from the existing main and connected to the temporary main. Generally, the connection to the service will be made outside of the curb cock, but even in that case, it will be advisable, when using hose connection, to put a cock between the hose and the outlet from the temporary main. This second cock allows a quick shut-off in case the hose connection pulls off or in any way develops a leak not capable of quick repair.

The temporary main will usually be supplied with gas through one (or preferably two) connections tapped into the existing main system. In the case now under consideration, viz., where a temporary main is used only during the laying of a new main, it is seldom necessary to make any provisions for

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condensation in the trap formed by the service connection above described. Where, however, temporary mains are laid because of the forced removal of permanent mains during the progress of street work, and temporary supply will continue

Fig. 21.—Temporary Main.

during cold weather, ample drip provision should be made at any trap.

Figs. 21 and 22 illustrate some features of temporary main work.

SUPPLY IN ABSENCE OF ANY MAIN.

The case in which the existing main must be removed to allow room for the new main, no temporary main was possible, and consumers using gas at all hours of the day, would undoubtedly prove to be very rare. Where the existing main was fed from two directions, it could be cut out at the end from which the new main was being laid without installing a by-pass. Then the problem of main laying would

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consist in removing the existing main in as small units as seemed practicable, and in purging the new main in small

Fig. 22.—Temporary Main.

sections as laid. Holes for services would be tapped in the new main before laying, and would serve as successive purging and bag holes. In this way, no consumer need be out of gas

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more than one or two hours, and by special expedients this time could be greatly reduced. For instance, a temporary pipe might be run from the top of the street tee in the last service on the new main, to connect with the service, or services, being disconnected from the section of existing main just taken out to make way for the next section of new main.

Where the existing main was only fed from one end, and this was the end from which the new main was laid, a by-pass would, of course, have to be installed to feed the existing main, and with the progress of the new main, the position of the by-pass would be continually changing.

REFILLING.

GENERAL CONSIDERATIONS.

In refilling, there is always an opportunity of skimping work, entirely absent in the case of trenching. The great saving in labor afforded by loose filling or puddling, as compared with tamping and ramming, often results in the adoption of one or the other, where not only the best interests of the work, but also of the public, require that ramming should be done. In discussing the conditions that should be kept in mind in deciding on any particular method, this general rule should never be forgotten, viz., that the public has a right to expect such refilling as will restore as promptly as possible to its original condition, the surface of any trench in any roadway, where traffic is seriously incommoded until such restoration is complete.

Unless the expense is very great, only good soil should be in close proximity to a main, and cover it by a layer six inches to a foot thick. This is especially important where the main is of wrought iron or steel and the good soil is substituted for ashes, cinders or city refuse. Cast iron is not nearly so subject to corrosion, but still good soil around it is advisable. The objection to refilling with small or large stones or broken rock, hinges entirely on the question of future repairs. If the trench is not apt to be opened to any great extent, as would be true

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of most small main jobs, a large expense for soil to replace the excavated rock would not be justified. However, it often happens when solid rock is encountered, that the excavated material can be sold on the trench side at a slight profit, thus paying for the substituted earth.

During the winter time when the excavated earth freezes, it should be broken up as far as feasible, both as excavated and after being frozen, before refilling, because the larger the lumps replaced, the less the material returned to the trench, and the more settlement occurring after the frost goes out. As far as possible, unfrozen material from the centre of the pile should be placed around the pipe. When other conditions are acceptable, and the temperature is not so low that the water will freeze, instead of thawing the frozen lumps, puddling may be used to advantage with frozen material.

The character of the temporary surface over the trench in those cases where repaving does not follow immediately upon refilling, will vary with the kind of paving and will be discussed under the head of "Repaving."

RAMMING.

Ramming should be the practice wherever there is much travel along and over the trench, or where repaving must follow immediately. It is accomplished by tamping and ramming solely, or in combination with puddling.

If the main has been laid with cement joints, dirt has been tamped under and along side of, and rammed on top of, the pipe a depth of several inches, except at the bell holes. If lead has been used, the amount of refill that has been done prior to the completion of laying work, will depend upon the necessity for strengthening the trench or keeping the laborers busy. In any case the first refilling work after the pipe has been laid, tested and purged, is to cover any existing uncovered portion of pipe, and where compact filling is necessary, there should be for every shoveler on the bank two men in the trench, tamping the earth under the pipe and between it and

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the trench sides, and then after the pipe has been covered, or a sufficient width of trench reached, changing to a rammer. When first tamping around a pipe, which is not held in position by any earth, the tampers should be in pairs, one on each side of the pipe, working against each other and thus preserving the alignment. Both in tamping and ramming, the lowest point on the trench should be refilled first, and the refilling thereafter carried on in horizontal planes.

For any mains larger than 12", an economic width of trench for all laying purposes, will not afford room enough on each side of the pipe to ensure that the space between the bottom of main and of trench is filled even loosely, and therefore, unless there is a willingness to incur extra excavating expense, it must be understood that there will be under all large mains a space of varying dimensions, which will afford a gas leak a fairly free passage. However, this is about all the harm done, with the resulting chance of making the exact location of a future leak somewhat harder. If the main is properly blocked, it will not settle, and if the trench is elsewhere properly filled, the hollow under the main will cause no earth settlement. Nevertheless, because it is impossible to entirely fill the space under the main, does not mean that no effort should be made to fill as much space as tools and trench will allow. The larger the main, the more attention should be paid to this first tamping, and the better the laborers assigned to the work.

With a proper proportion of rammers to shovelers and the right kind of rammers, which mean men able to and paid to ram *hard*, there will usually be no difficulty in replacing all material removed for mains 8" and smaller. On larger mains, where earth has to be hauled away, an accurate account should be kept of such removed material, and if it exceeds the volume of the pipe laid, an explanation should be forthcoming from the foreman.

In recent years power rammers, driven by gasolene or compressed air have become available. They are probably still in an experimental stage, but with the increasing difficulty of pro-

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curing good labor, the value of such machines, both as labor saving devices and as ensuring proper ramming, will increase.

In any refilling, but especially in ramming, care is necessary to protect from injury, all small pipes exposed in the trench, especially any lead water services. These, where over the pipe, should be blocked from it, or if under, from the trench bottom. In either case the blocking tends to prevent any pressure of the earth on the lead pipe, pulling it out of the water main. Ramming over terra cotta pipe should be carefully done to prevent a smashing in and possible stoppage.

If the trench is to be paved at once, refilling should stop at the point below the surface where the paving base begins. Otherwise, the trench should be filled to the street surface, or at the most, only slightly mounded. If it should happen for any reason that material is lacking, enough should be procured to leave the trench surface flush with the rest of the roadway.

Occasionally in trenching, it is advisable, or necessary, to tunnel under certain paving or structures. These tunnels usually exist in connection with trenches refilled by ramming or puddling. Ordinarilly it is more economical to break down the tunnel roof, than to refill from the sides. Of course, where structures such as street railroad tracks, with concrete road bed, are concerned, breaking down is *not* the right course.

PUDDLING.

Puddling appeals to every foreman because of its cheapness, and should be practiced wherever the conditions are favorable, *viz.*, where the soil is of the right kind, and there is no danger of water soaking into cellars, or undermining the pipe. Puddling in a street made of filled in material, may cause a general sinking of the street surface. In built up sections, puddling may be objectionable because of the chance of water getting into cable conduits, or because of the inability to pave at once upon the puddled material.

When puddling has been decided on, the pipe should be covered at least six inches by well rammed earth before any water is let in. Also, if the trench has over 5 per cent. grade,

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the first ramming should reduce the grade to this figure, in order to prevent any wash under the pipe by water sinking through the loose fill. Dams at frequent intervals will also serve to prevent any scouring out by water flowing down a grade, and in any case, dams would be necessary to confine the water to each terrace made by the first ramming.

The preliminary ramming being done, the trench is filled to about one foot of the surface, and then water turned in. Usually the water is obtained from the nearest fire hydrant, hydrant keys being furnished by the municipal authorities, often on payment of an annual fee. Care should always be taken to avoid injury to paving by the flow of water over it. As the water flows along the ditch, bars are hand driven through the loose material into the rammed earth alongside the pipe. As the bars are driven down, they are swung around in a circular direction, and the funnel shaped holes so made allow much water to soak into the earth around the pipe and perhaps carry earth to fill any voids under the pipe, but there is no chance for a flow of water rapid enough to affect the stability of the pipe. As the earth sinks under the action of the water, more earth is added, especially when needed to preserve any desired channel for water flow, which is not stopped until the earth is well saturated and water runs over it without being absorbed. Then the remainder of the earth is thrown in and lightly rammed into a slight mound over the trench surface. Too much ramming is to be avoided, as it tends to produce a spongy condition. Too much water is also to be avoided, as tending to soften the bed of the trench, causing the pipe to settle and to make the refilled material so soggy as to delay repaving. Ordinary labor cannot be trusted unwatched on work of this nature.

The method above described is considered preferable to the practice sometimes followed of throwing in all the earth and digging a trench in the centre of the mound for the water to follow. Such a procedure leaves no dry earth to finish off the trench.

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Where services are laid in connection with the main work, especial care should be given to the repair of the opening made in the house wall, if there is to be puddling and the water line will be higher than the service opening. Of course, the more porous the soil, the more reason for a good cement coating, both on outside and inside of wall. Also, a dam of dirt should be thrown across every service trench at its junction with the main trench.

LOOSE FILLING.

Naturally the largest amount of main work will consist in extensions to the existing system, made necessary by new buildings and usually such extensions are laid in unpaved streets. With the ordinary size main and an interval of some months elapsing between laying and paving, there can be no objection to loose refilling of the trench, leaving to time and street traffic the gradual consolidation of the refill. In such unpaved streets there are always many trenches beside those made for gas purposes, and the roller used by the paving company is relied on to compact the entire road-bed.

The surface of this trench after a loose refill is that of a mound perhaps a foot high. This serves as a warning to wagons to keep away. It is incumbent on the gas company to make a frequent enough inspection of the trench to ensure the prompt filling of any dangerous holes that may be formed after a hard rain. Also, a certain amount of trimming of the mounded earth may be required from time to time.

CLEANING UP.

The final cleaning up after any main laying job can only take place when repaving is complete, but as in many cases the repaving is done by a contractor; such cleaning up as may be done before repaving and by the company's employees, will be treated of now.

Almost any one can open trench and obstruct and dirty a street and footway. Few contractors on street work ever clean up properly. All gas companies should see to it that

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the natural disgust induced in the occupants of any street at seeing it torn up is followed as quickly as possible by a feeling of satisfaction at the prompt execution of the work and the thorough restoration to conditions previously existing. A broom and sufficient buckets of water are aides not often enough used in the final stages, but they are generally needed to do justice to the occupants' property in the removal of all earth stains on the house fronts, side walks, tree trunks and boxes, grass, etc.

In this connection, good planning of a job to be sure the difficult portions are not neglected, will do wonders to make the work move along continuously and not leave any gaps remaining open for days after the work on each side is finished.

REPAVING.

GENERAL CONSIDERATIONS.

It is not considered advisable to describe the art of paving, and this not only because it would add to the length of a treatise already very long, but also because many companies find it advisable to contract their paving. This tendency is increased by the growing prevalence of asphalt, the restoration of which by the company is out of the question. In the old days when cobble and rubble were alone met with, a few paving tools and a little sand were the only equipment needed to enable every main and service gang to restore their own paving. So far only roadway paving has been in mind. A like change has occurred in the footway. Cement has given place to bricks, and again the new form requires more skill and equipment in its restoration than did the old. Therefore, as has been said before, the tendency is to contract out the paving. This involves more lamping of trenches, rather more office work in connection with paving bills, and possibly more inspection of paving work, though with reliable contractors their work need not require any more attention and inspection than would company paving. By inspection, two results are obtained: No poor work is allowed to remain, as an annoy-

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ance to the public and a bad advertisement for the company, and no dangerous holes may exist long without detection. As the details of an inspection system will vary greatly according to local conditions, no description of one will be given here.

ASPHALT.

If the street is a much travelled one, it is advisable to leave the trench in such shape that it may be driven over during the interval between refilling and repaving. This condition has an added advantage that it dispenses with the expense of lamping the trench. When the material has practically all gone back, the concrete of the base (if any) should be thrown in on top of the earth, and then the asphalt pieces laid down. If the pieces have been well cut, a very good job can be made. In some cases of service trenches on important streets, with extra care in cutting the asphalt, and the use of a little cement in the cracks between the pieces, a very fine temporary job results. Again, the base material may be left along the trench or at the curb in piles and just the asphalt laid back, or the asphalt may be left piled up and the trench surface finished off with the base materials. In most cases, however, it is probably true that the surface of a long trench cannot economically be made safe for bicycles or motor cycles, and if there is much of such traffic, it would be necessary to lamp the trench until repaving.

In order to ensure prompt repaving, it is advisable to provide in the contract for decreased prices for all delayed work. For instance, if paving is supposed to be laid within four days of receipt of notice, seven-eighths price might be paid for paving laid five days after notice, three-quarters price six days, etc. Also, the use of concrete base under all asphalt, whether the original paving had such base or not, will result in a gratifying absence of settlement, a condition always glaringly apparent in asphalt.

In towns without any asphalt plant it will generally be satisfactory to the municipal authorities to substitute a cement

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finish on a concrete base for any asphalt torn up, this being regarded as temporary repaving only, and being replaced on the first occasion that asphalt material is available.

CONCRETE BASE PAVING.

Most modern street paving is laid on a concrete base, and the tendency of this class of paving, as with asphalt, is to intrust its restoration to a contractor. Usually the more or less broken masses of concrete form the surface of the trench as left by the rolling gang. Whether such a trench will need lamping or not until repaved will depend on its location, the compactness of its top surface, the amount and character of traffic, etc.

ALL OTHER PAVING.

Under this head falls vitrified brick, belgian block, cobble and rubble, all on sand base. Where small openings only are made in such paving, there are many arguments in favor of its restoration by the same gang that did the opening. In other words, on detached service or lead work, the ability of the gang to do its own paving will save all lamping cost, as well as a certain constant expense entailed by unpaved trenches, such as water in cellars. Also, it is possible to get better paving done by the company's men than by the contractor's. When opening in a street requiring sand between the paving stones, one of the obligations of a gas company, in order to ensure a good job, is to see that such sand is actually brushed in between the stones and not left on top to be a nuisance on windy days.

As a rule, however, the fact that much of the paving is better contracted for, will incline the average company to contract for all. In doing so a bigger profit is often paid to the contractor than is realized, until it is found by experience how cheaply, with proper organization, sand base (and even concrete base, if there is enough of it) paving can be done.

Below is given some information as to equipment useful in paving work:

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PAVING SMALL OPENINGS AROUND STOP BOXES, ETC.

1 Light push cart similar to a plumber's push cart, containing:

1 Spoon bar
1 Street broom
1 Small galvanized bucket
1 6" Cold chisel
1 Stop box cleaner
1 Brick hammer
1 Caulking hammer
1 Pick
1 Sharp nose D-handle shovel
1 6" Trowel
Cement, sand and bricks

PAVING SERVICE AND SMALL MAIN OPENINGS.

1 One-horse open body spring wagon, with a small top over the seat for the protection of the men, containing:

2 Street bars
1 3'x4' Mixing board
1 Street broom
1 Dust brush
1 Galvanized bucket
2 Cold chisels
1 Paver's straight edge
1 Curb or radius edger
1 Wooden float
2 Brick hammers
1 Caulking hammer
1 Concrete knife
2 Picks and handles
1 Pitchen tool
2 Diamond points
1 Rake
1 Belgian block or paving rammer
1 Dirt rammer
1 Dot roller for cement
1 Seamer
1 Flat nose D-handle shovel
1 Sharp nose D-handle shovel
1 Sieve
1 Finishing trowel
1 4" Trowel
1 8" Trowel
1 Monkey wrench
Paving supplies such as cement, brick and crushed stone, etc.

This equipment is sufficient to do, on a small scale, all kinds of paving except asphalt.

PAVING LARGE MAIN OPENINGS.

For extensive paving the number of tools listed just above is increased depending upon the amount of paving to be done.

RECORDING.

REASONS FOR RECORDS.

A knowledge of the number of feet of each size of pipe comprising the street main system is valuable at all times, and very necessary when a valuation of the mains is required.

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This knowledge, subject to varying degrees of error, is possessed by every company, and almost always presupposes the possession of a map showing the location of the mains by sizes. In many cases, however, not only is there great uncertainty as to the correctness of the sizes shown, but also the location as measured from the property or the curb line, is either wanting or incorrect. This lack of proper records is often the natural consequence of the fact that in the beginning the location and size of every main was easily a matter of memory for the few employees. As the system grew and new employees succeeded the old, there was failure to transfer records from brains to paper. Another reason for lack of records, or improper ones, is carelessness in past years in preserving and entering the information furnished when the main was laid.

At present the necessity for proper street main records is thoroughly appreciated, and the problem has been solved in many different ways, depending upon differences in local conditions and in the human equation. In what follows, will be found a description of methods of which experience has proven the worth.

SYSTEM OF RECORDS FOR NEW MAINS.

In determining the character of requisite street main records the usual condition is that of a main system sadly lacking in data regarding existing mains, and therefore needing records of maintenance as well as extension work. Before considering this condition, the rarer one will be considered, where an entirely new main system is being installed either for a competing company, or for the first company in any locality.

FIELD RECORDS.

For the field record, that is, the one taken out on the work, a Transit Book is very convenient. This is 4½" x 7⅛", has about sixty leaves, and is ruled with horizontal and vertical lines. In making the records, a zero point may be taken at the beginning of the line, and all locations along the line given

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with reference to this zero. For long lines, especially in country roads, this is the best way, and it is also very convenient in city streets. Following this method, once the proposed line of a main has been measured over, and the position of all desired points of reference noted, any portion of the main as laid can be quickly shown on the record, no matter whether gaps occur or not.

The amount of record that will be needed to enable the main to be properly located on a map, and also easily found where occasion requires uncovering, will depend entirely upon the number of changes occurring in depth and alignment. The depth to top of pipe and the distance out from the curb, or property line, should be given every one hundred feet when there is no change, and where the dimension is changing, at enough points to define the line. A single line will suffice to show the pipe. All special castings, whether branches or bends, should be accurately located, the length of each special being considered to be the distance between the faces of its bells, where it has two bell ends, or between the bell of adjoining pipe or specials, when the special being measured has two spigot ends, or between the bell of the special and the bell of the adjoining pipe or special, where the special being measured has one bell and one spigot end. A bracket mark, "]," at right angles to the length of the pipe is an easy way of representing the face of every bell, the horizontal lines extending away from the face of the bell.

When the points of reference along the main, such as dividing property lines, intersecting roads or streets, etc., are not at right angles to the main, these points should be located by their intersection with whatever line is being used as a base to measure distances at right angles to the main; and not by their intersection with the main itself.

With all specials thus located at the proper distance from the assumed zero point, the amount of straight pipe laid at any moment, may be easily calculated, and in some cases, this is an easier way of getting it than by adding up a series of

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figures showing the work day by day. Any portion of the line, where the depth is changing rapidly, or where the pipe is not parallel to the reference line, must be measured along the pipe itself, and such measurement recorded and used, instead of the distance as measured on the reference line between the stations marking the beginning and end of such deviations in line and depth.

When there are many specials in close proximity, which usually means many changes in depth and alignment, the scale sufficing for the ordinary portions of the line will prove too small. Therefore, either the scale ought to be increased at these points to give a proper sketch, or else a detail sketch on a larger scale should be shown elsewhere.

While, as a rule, the depths would indicate which way the line was dripping, at the same time it is surer and much more convenient for purposes of permanent record, to indicate the direction of drippage by an arrow, parallel to the line and pointing with the flow.

A record of other structures encountered is generally of sufficient value to warrant the slight extra work so involved. This record of foreign structures increases in value as underground conditions become more congested, and when there is another gas company, whose records are probably not very complete, any records of its mains are apt to prove very useful, either in competition or consolidation. Where the foreign structures are mains, they can be indicated in the same way as the main being laid, though probably not in so much detail Where they are conduits, and therefore almost invariably rectangular in section, a line may be drawn indicating the nearest upper edge to the main being laid. This, in connection with the distance from the centre of the main, the breadth and depth of the conduit, and depth of its top surface below the street level, locates it completely.

It is of value to indicate on the record the date on which each foot of main is laid. This is very easily done by placing the date of each day's work between arrow heads, located at

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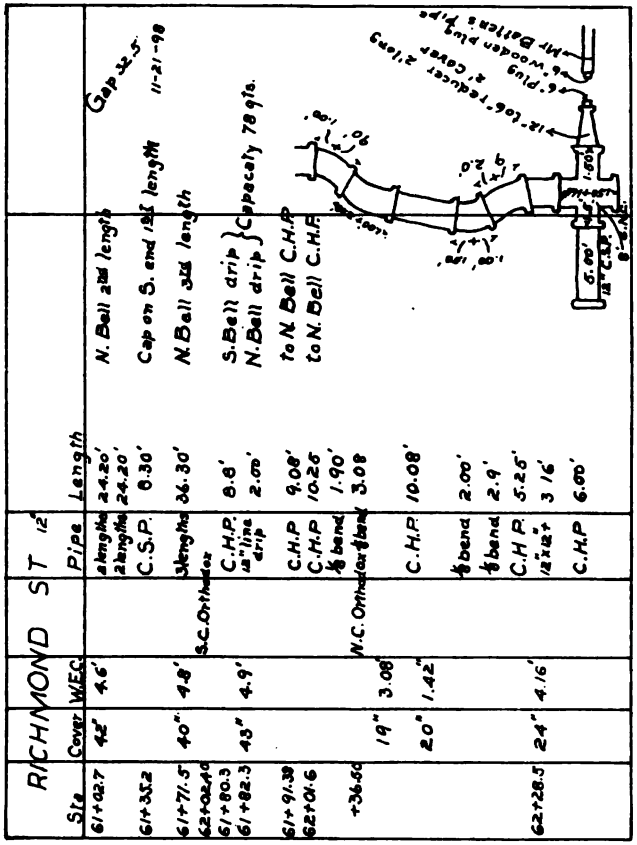
the proper points. Where, for any reason, the work is quite discontinuous, this graphical record of dates may prove quite



Sta	Cover	W.E.C.	Pipe	Length
61+02.7	42"	4.6'	2 length	24.20'
			2 length	24.20'
61+35.2			C.S.P.	0.30'
61+71.5	40"	4.8'	3 length	36.30'
62+02.40			S.C. Orthotar	
61+80.3			C.H.P.	8.6'
61+82.3	43"	4.9'	45° line drip	2.00'
61+91.30			C.H.P	9.08'
62+01.6			C.H.P	10.26'
			1/4 bend	1.90'
+36.56			N.C. Orthotar tank	3.08
	19"	3.08'		
	20"	1.42"	C.H.P.	10.08'
			1/4 bend	2.00'
			1/4 bend	2.9'
			C.H.P.	5.25'
	24"	4.16'	12"x12"	3 16'
62+28.5			C.H.P	6.00'

Fig. 23.—Transit Book.

valuable as a history of progress and of work condition from day to day.

Fig. 23 shows several pages of a Transit Book with a record made out according to the ideas above given.

REPORTS TO OFFICE.

Where the company is a small one no work progress report to the office is needed, as the information can be obtained by

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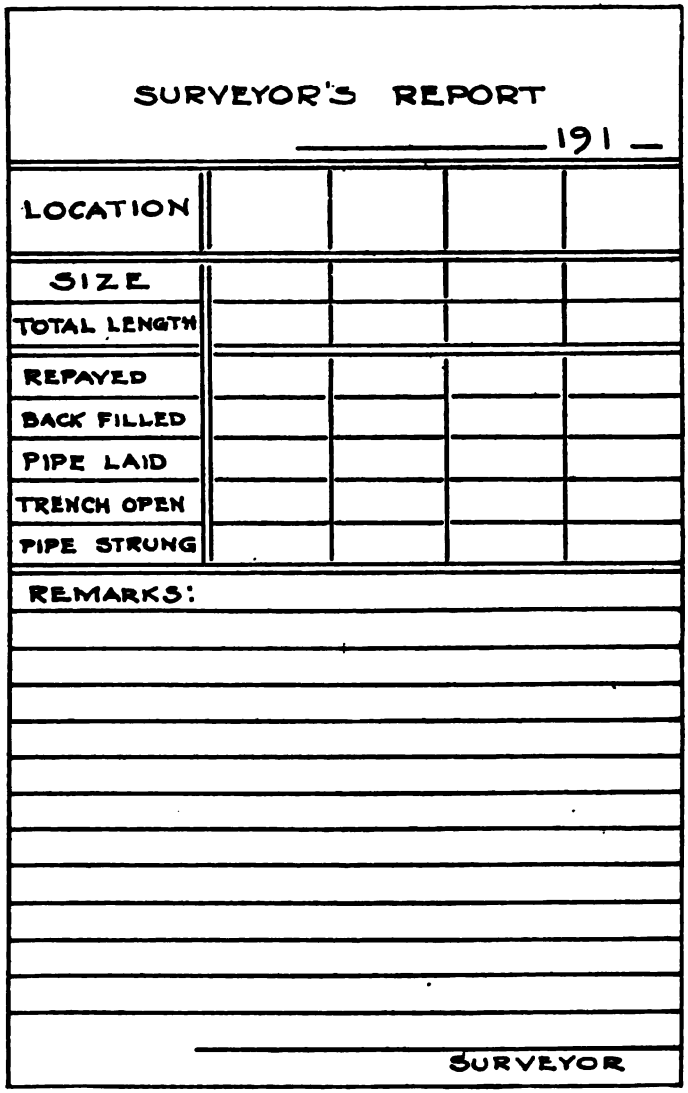
an inspection of the field book, or is a matter of personal



SURVEYOR'S REPORT

_____ 191 _

LOCATION				
SIZE				
TOTAL LENGTH				
REPAVED				
BACK FILLED				
PIPE LAID				
TRENCH OPEN				
PIPE STRUNG				

REMARKS:

_____ SURVEYOR

Fig. 24.—Postal Card Progress Report.

knowledge with the main foreman. When these conditions no

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longer obtain, and a daily or weekly report is needed, a form as shown in Fig. 24, should be used, printed on a postal card where mailing is necessary. "Repaved" shows the total number of feet repaved to date; "Back Filled," what has been filled but not repaved; "Pipe Laid," the amount of pipe laid where trench has not been refilled; "Trench Open," the amount open in which pipe is not yet laid; "Pipe Strung," the number of feet of pipe delivered on the work and not yet laid. This information is particularly valuable in the case of a long line, and gives the office a clear idea of what the physical condition of the work is at the time of report.

PERMANENT RECORDS.

The best form of permanent records for the conditions we have been considering all along, viz., an entirely new system, will depend somewhat upon the maps and their scale that are available for the streets occupied. For all large and many small cities, atlases may generally be obtained with plates whose scale varies from 200 to 500 feet to the inch. There are very few small towns for which maps are not obtainable, and in the country there are usually the maps of the Geological Survey to fall back on. No company should make up its own map except as a last resort, for map work easily runs into great expense.

On the map a line will indicate by its color the size and general location of a main, but the scale will be too small to make it advisable to indicate specials, drips or any details of line. To get such details, a different set of records is wanted, except indeed in companies selling say less than fifty millions a year, in which the original field book record will, with the map, supply all necessary information. When the field book is used, the map should indicate field book number and page containing the record of every block, or say 500-foot section of main. In this way an inspection of the map shows at once where to go for the detailed record.

When the field book information is transcribed, the desirable

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unit for the new detailed record is either the city block, or for country roads for lines under 1,000 feet, the total length of main, and for lines over 1,000 feet, some fixed distance, such as 500 feet. The material used for the record should be something like tracing cloth, or thin bond paper, from which blue prints may be made to form the working file, while the originals themselves are kept in a fire-proof safe. Each sheet should be about 7" x 18", and should give the main in plan and in elevation, and be a faithful transcript of the field record in every point necessary to give a proper idea of the location of the pipe and of other structures encountered. The drawing need not be to scale, and in this way speed may be gained and more space given to points on the line where many specials were used. Each sheet should be numbered and the various sheets numerically arranged in groups of one hundred. The general map, or maps, would in this case bear the proper record numbers opposite each block, or unit distance. Thus, to find any detailed record, it would only be necessary to look at the map, see the block number, and turn to the proper group of detailed records, where in its numerical order would be found the record desired.

When there is much occasion to refer to the detailed main records, the above system is exceptionally valuable, because of the quickness with which the records may be found. Where, for any reason, such as for instance to locate a main for a service gang, it is necessary to send a record on the street, a convenient way is to make a rough free hand sketch on a white scratch pad, 5½" x 8½", in triplicate, by means of carbon paper, of the location wanted, give all three the number of the record from which taken, send one sketch on the street, and file the other two numerically. The service man should be instructed to return the sketch, and no other sketch need ever be made for that particular location, until all three are lost, or worn out.

Where the record may be needed on the street by the main foreman, there is, of course, no reason why the proper blue

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print should not go out, but for service work the sketch system is preferable.

SYSTEM OF RECORDS FOR NEW AND EXISTING MAINS.

SMALL COMPANY.

Coming now to the condition that confronts the average distribution man, *viz.*, a main system that is being enlarged every year, and that is also lacking in proper records of many existing mains, two systems of records could be used, one for the new mains along the plan already described, and another system for the old mains, the exact location of which is unknown. Where the company is selling less than fifty millions annually, which means a small town with few underground structures and few specials in the main system, one of the most convenient and easy ways to record information of old mains, as obtained from time to time, and to collect this information in a convenient shape, from which to make a graphical record later on, is by the use of the book, of which a specimen page is shown in Fig. 25.

The book was written up for every street on which mains were known to be, and distances shown between each intersecting street. As illustrated "O" is the east fence line of Erie, and "202" the east fence line of Huron, which is also taken as "O" for distances in the next block. One line of the book was allowed for every 25 feet, and any work done on a main, or information gathered by uncovering it, was entered on the proper line according to the location. Of course, if there were to be many openings, this book record would not provide adequate space, and therefore it is only recommended under the conditions already described. As will be noted, it also affords an opportunity for recording leaks.

To record the new mains of the small company just considered, the field book record, as described on page 96, with no transcribing, would be very adequate.

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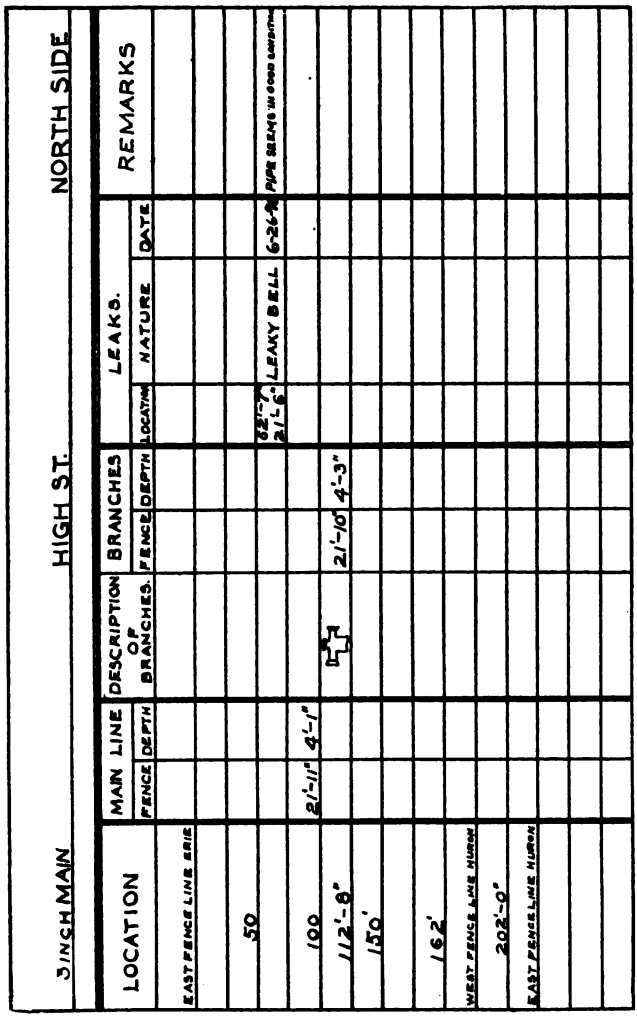
LARGE COMPANY.

The larger the mileage of mains, the more argument there



3 INCH MAIN — HIGH ST. — NORTH SIDE

LOCATION	MAIN LINE		DESCRIPTION OF BRANCHES.	BRANCHES		LEAKS.			REMARKS
	FENCE	DEPTH		FENCE	DEPTH	LOCATION	NATURE	DATE	
EAST FENCE LINE ERIE									
50						82'-7" 21'-6"	LEAKY BELL	6-26-[illegible]	PIPE BEING RE-CAULKED
100	2'-1"	4'-1"							
112'-8"				2'-10"	4'-3"				
150'									
162'									
WEST FENCE LINE HURON									
202'-0"									
EAST FENCE LINE HURON									

Fig. 25.—Main Record Book.

probably is for the use of one system of records, for both new

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and old mains, although where, as is very often the case, the greatest amount of new mains are laid in one or two comparatively restricted areas on the outskirts of a growing city, there would be no confusion resulting in one system of records for these new mains, and another system for all others. Going still further, it is quite feasible to lay all new mains according to the field book system, and by means of the number on the general main map, it could be told at once where to look for any particular record. The presence of a number opposite the block, for which the record was desired, would indicate that such record was made according to the field book system, and would be found as a blue print in the pile(or file) indicated by its number. The absence of a number would indicate that the record was on a sketch card (to be explained later on) and would be found in the proper alphabetical file.

The great value of the blue print record lies in its presenting a continuous record of the main, but it does not lend itself to changing conditions, and this is one of the greatest objections to using it in large cities, where, apparently for many years to come, the installation of various underground structures, especially wire conduits with their attendant manholes, will cause many changes in main locations. To meet these conditions, the system of records used in Philadelphia, alike for new and for old mains, has proven very successful. Before describing it, a general account of the Philadelphia organization for obtaining records is advisable.

SYSTEM OF RECORDS IN PHILADELPHIA.

ORGANIZATION.

There is a Superintendent of Records reporting directly to the Engineer of Distribution. Under him is a Chief Draftsman in direct charge of obtaining, mapping and filing records, through the agency of street clerks and draftsmen. A street clerk is usually a graduate of a technical college or institute. Upon employment he is first put to work in the Records Division to familiarize himself with the system of records, one

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of his duties being the duplicating of records. After this inside apprenticeship, he is sent out to record the work of one or more street main gangs. In this position he is able to learn all the details of street work, and to qualify for the position of foreman in charge of main or service work. The position of street clerk, besides serving as a training school for future foremen, superintendents and managers, allows the gang foreman to devote his entire time to directing his men. When the foreman is held responsible for his main records, either the records or the work, or both, are apt to suffer.

The draftsmen in the office, post upon the main charts the records as made by the street clerks, and also furnish various reports needed in connection with main work.

Each street clerk is provided with the following equipment:

1 45°, 6″ angle
1 60°, 4″ angle, for field book
1 Brass plumb bob
1 Note book, 3¾″x6″, 100 leaves
1 Sketch book, 4½″x7⅛″, 60 leaves
1 Piece of yellow chalk
Clips and fasteners of various kinds
1 Chalking cord
1 Band dater
1 Street directory
1 Set of ink eradicator
1 Combination ink and pencil eraser
1 Draftman's soft pencil eraser
1 Holder for Daily Progress Report
1 Black, blue, red, brown, green and yellow drawing ink
1 Set of instructions to street clerks
1 Set of drawing instruments
2 Ink pads, one red and one black
1 3-H lead pencil
1 Medium lead pencil
1 6′ extension rule
1 Piece of soapstone
1 Set of rubber stamps
1 50′ metallic tape
Pens, blotters, printed forms and other stationery

FIELD RECORDS.

A field record is made of all openings. A standard field sketch is shown in Fig. 26. As all subsequent records depend upon the field sketch, the measurements are carefully taken and clearly plotted in every detail. Memory is not relied on in any way for information necessary for the final record. A 3-H pencil only is used for this field work. Each sketch is indexed at the back of the field book, alphabetically by its

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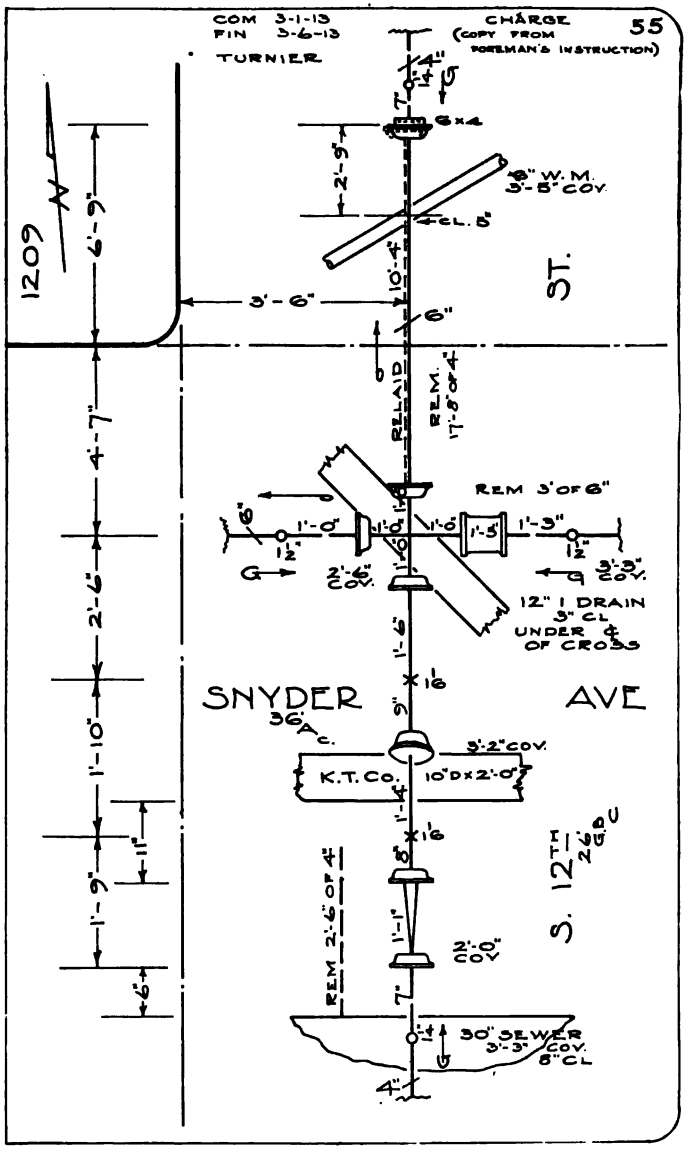

Fig. 26.—Field Sketch.

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street name, and when the book is full it is turned into the office where it is dated and numbered.

In making field sketches the following points are observed in connection with measurements:

USE OF MEASURING EQUIPMENT.

Fig. 27 shows, in a general way, the application and use of the tape line, measuring rule and plumb bob. The tape line is drawn sufficiently taut to bring it to a straight line, but is never stretched, and as much as possible it is protected from the weather. If it becomes wet or soiled, it is dried before winding into the case. Every two weeks each tape is tested for length against a steel tape. In using the plumb bob, three trials are made for each measurement taken.

MEASUREMENTS: HOW AND WHEN TAKEN.

Curb lines are used as bases of reference wherever possible, otherwise building or fence lines, car tracks, etc. All measurements at right angles to a main or street axis (known as "ordinate" measurements), are taken from the nearest curbs and measured to the centre of the main from the outside edge of the nearest curb. Ordinate measurements are taken at all angle points in the line. Ordinate measurements of foreign structures are always taken with reference to the centre of the nearest gas main, and are to the nearest *edge* of rectangular structures and to the centre of circular structures. Ordinate measurements of foreign structures with reference to curbs are not ordinarily taken.

All measurements parallel with a main or a street axis (known as "axial" measurements) are taken from the intersection of the curb serving as a base for the ordinate measurements, with the intersection, actual or produced, of the nearest curb of the nearest intersecting street. Where streets intersect at angles other than right angles, measurements are taken as shown in Fig. 28. The intersection of the curb lines of such angle streets is obtained by the crossing of the two lines of cord extended along and in line with the curbs whose inter-

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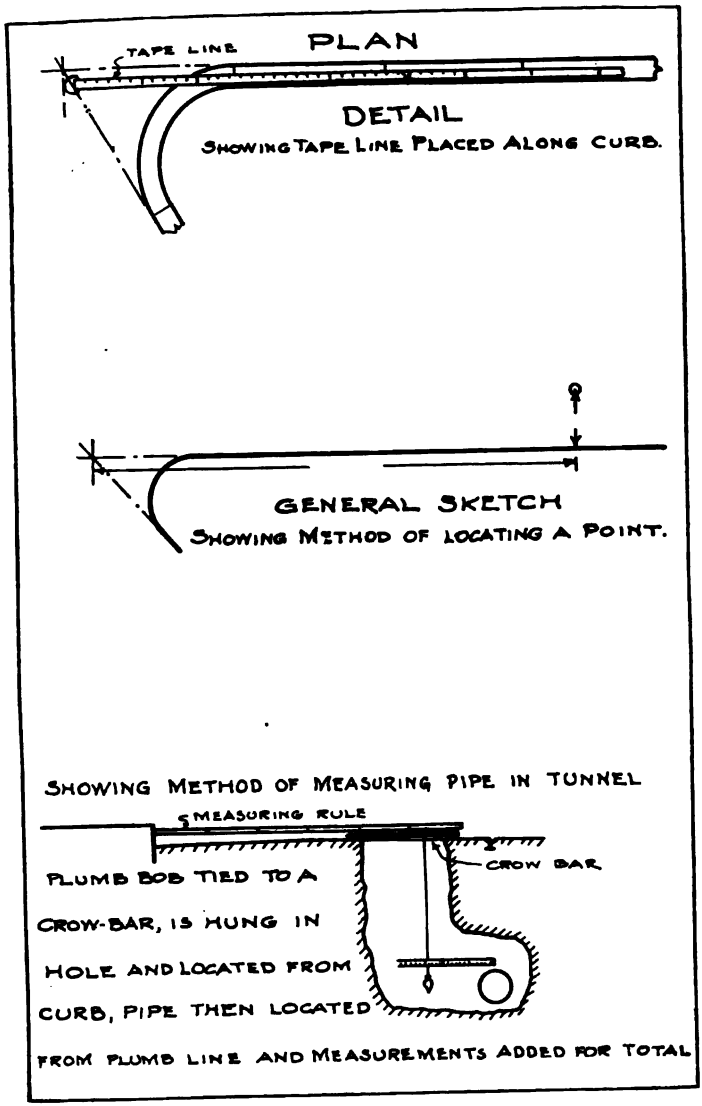

Fig. 27.—Measuring Equipment.

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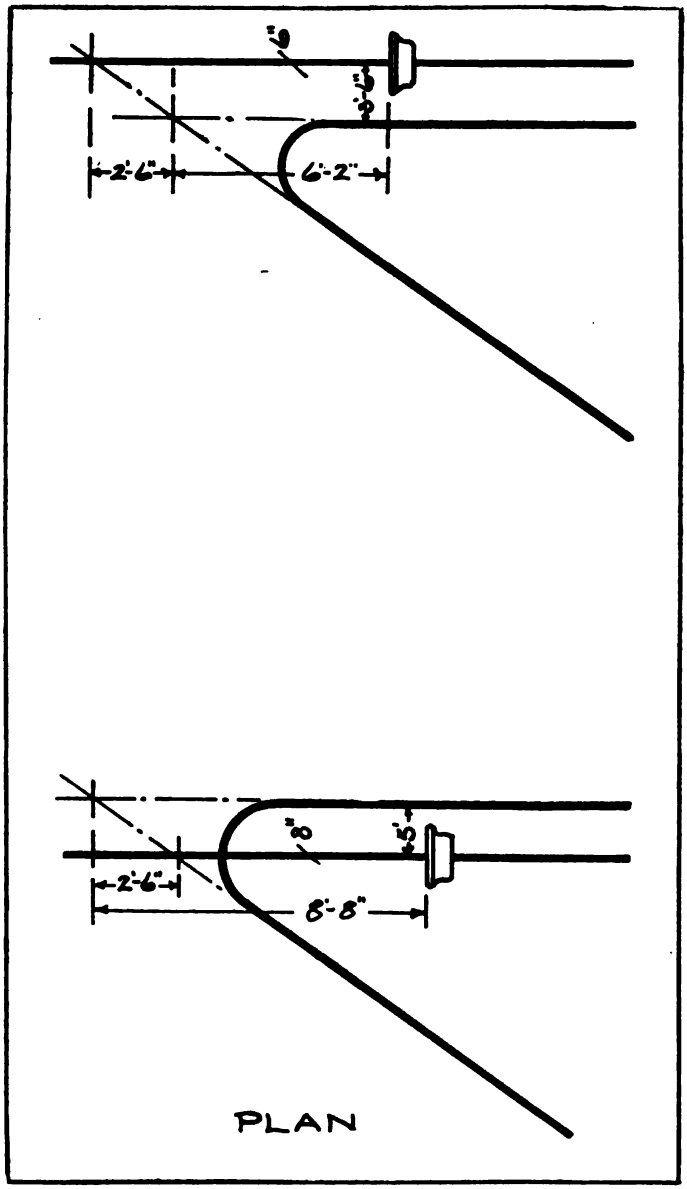

Fig. 28.—Measurements at Other Than Right Angles.

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section is desired; or by using a chalk line, the intersection may be found with the aid of one cord only.

All depths are taken vertically from the top of the street surface to the top of all structures. Elevations are not shown in the field book unless the structures to be sketched are quite complicated, as it is thought the ordinary plan will not show conditions clearly.

Axial measurements on branches are taken from the intersection of the axes to the face of the nearest bell in all three, or four, directions. Axial measurements on bends are taken for each angle point to the face of the nearest bell, and are measured along the axis of the bend. Axial measurements on Y's are taken from the intersection of the axes to the face of the nearest bell in all three directions. Bushings are counted as being one inch long, and caps as four inches.

Other details that are necessary to bear in mind when taking field records can be stated to better advantage when describing how the permanent records are made.

REPORTS TO OFFICE.

Each day the street clerk makes a report in triplicate, one for the office in the district in which he is working, one for the Records Division and one for himself. This report is made on the form shown in Fig. 29. The form is self explanatory, except possibly as to the information called for in the lines opposite "Laid or Overhauled, Valve, Drip Services, etc." In these cases the character of the work is indicated by drawing a line through the proper significant letter.

PERMANENT RECORDS.

From the field book record a permanent record, known as the "sketch record," is made on the form shown in Fig. 30, whenever any pipe is laid, or old pipe uncovered, of which there is no satisfactory record. This form as well as Fig. 26 is quadrille ruled, not shown by the illustration. Where only a few feet of old straight pipe is uncovered and no foreign structures, the record is made on the form shown in Fig. 31.

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No.....To.....Inc. DATE.....

MAIN WORK DAILY PROGRESS REPORT

DISTRICT.....

LOCATION	SIDE	SIDE	SIDE	SIDE
INSTRUCTION NO.				
CLASSIFICATION				
SIZE MAIN	"	"	"	"
COMMENCED				
TOTAL LENGTH	'	'	'	'
DATE OF LAST REPORT OF INSTRUCTED JOB				
TOTAL OF LAST REPORT	'	'	'	'
REPORTED TO-DAY	'	'	'	'
TOTAL TO DATE	' TCH	' TCH	' TCH	' TCH
LAID OR OVERHAULED	L O SER	L O SER	L O SER	L O SER
ABANDONED TO-DAY	—OF "	—OF "	—OF "	—OF "
REMOVED TO-DAY	—OF "	—OF "	—OF "	—OF "
VALVE, DRIP, SERV. OR PRESSURE TEST. STA.	V D S P	V D S P	V D S P	V D S P
FINISHED				
FOREMAN				

LEAKS: .....

REMARKS. .....

.....

REC'D R. D. .....ST. CLERK.....

FORM 4—P.G.W. MAKE 3; ORIGINAL TO R. D., KEEP 1, 1 TO DISTRICT. 1520-1-17-13.

Fig. 29.—Progress Report.

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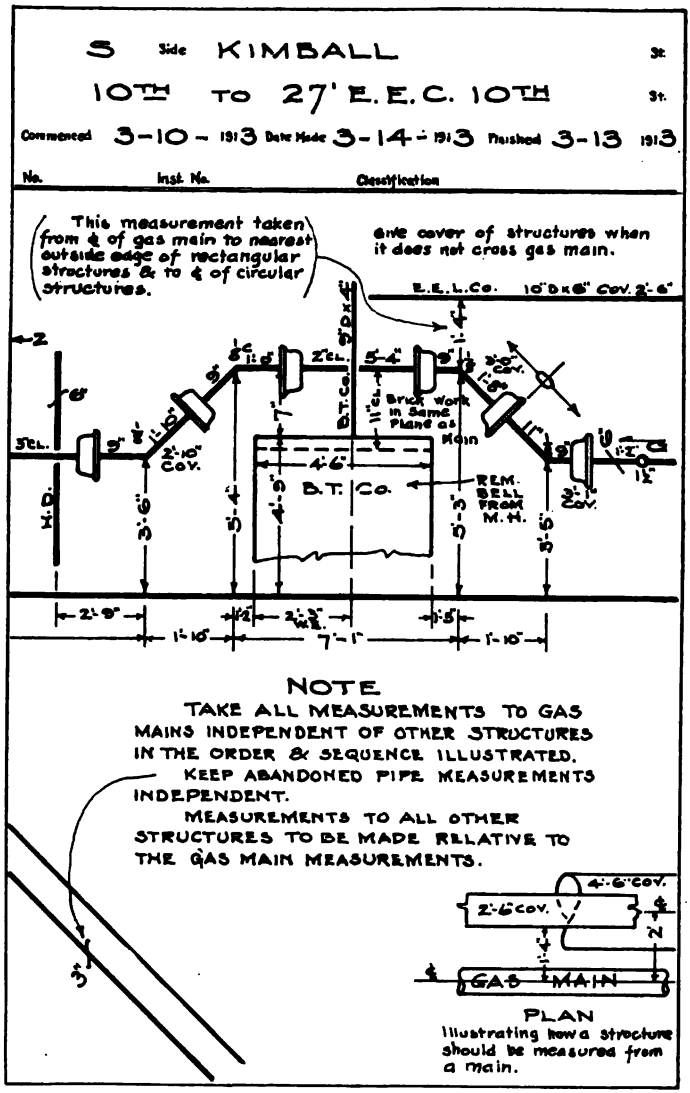
S Side KIMBALL St.
10TH TO 27' E.E.C. 10TH St.
Commenced 3-10- 1913 Date Made 3-14-1913 Finished 3-13 1913
No. Inst. No. Classification
This measurement taken from ℄ of gas main to nearest outside edge of rectangular structures & to ℄ of circular structures.
Give cover of structures when it does not cross gas main.
E.E.L.Co. 10"D x 6" Cov. 2'-6"
B.T. Co.
Brick work in Same Plane as Main
REM. BELL FROM M.H.
4'-6"
2'-10" Cov.
3'-2" Cov.
2'-8"
1'-10"
7'-1"
1'-5"
NOTE
TAKE ALL MEASUREMENTS TO GAS MAINS INDEPENDENT OF OTHER STRUCTURES IN THE ORDER & SEQUENCE ILLUSTRATED.
KEEP ABANDONED PIPE MEASUREMENTS INDEPENDENT.
MEASUREMENTS TO ALL OTHER STRUCTURES TO BE MADE RELATIVE TO THE GAS MAIN MEASUREMENTS.
4'-6" Cov.
2'-6" Cov.
GAS MAIN
PLAN
Illustrating how a structure should be measured from a main.

Fig. 30.—Sketch Record Data.

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SKETCH DETAILS.

In making the sketch record, Fig. 30, the following details are observed: Nothing is drawn to scale, but all of the structures are shown as they exist relatively to each other. The crossing of figures with lines and the crowding of figures, notes and lines are carefully avoided. The name of the street in which most of the work is done is given at the top of the form. The North Point is stamped in red in the upper left corner.

MAIN RECORD. ..... District.

Nearest house No. ..... St.

Charge

Nature of work ..... Date .....

Size ..... Cover ..... Ft. ..... Ins. ..... Drips towards ..... St.

Location of Main ..... Ft. ..... Ins. ..... of ..... Curb-line of ..... St.

Location of Joint ..... Ft. ..... Ins. ..... of ..... Curb-line of ..... St.

Kind of Joint ..... Joint recaulked Yes No. ..... Bell faces .....

Foreman ..... Kind of paving ..... Base ..... Kind of soil .....

Location of Foreign Structure ..... Size ..... Cover .....

Remarks .....

Rec'd B. of R. .....

Sign here .....

Form 33 P. G. W. Make 2—1 to Bureau of Records—1 to District. 10M-C-20-10

Fig. 31.—Main Record Card.

In general, the ruled lines of the record card are used in every feasible way, and when possible, the centre lines are used for the mains to be sketched, which are shown by lines 1/32" wide, according to the following scheme:

*Pipe laid in new work.....solid red
Existing pipe uncovered .....solid black
Pipe abandoned .....solid green
Pipe removed .....broken green
Pipe relaid .....solid red overlaid by broken black

*When wrought iron pipe is used, this fact is stated.

Foreign structures are indicated by lines 1/32" wide and the following scheme is used:

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Water mains .....solid blue
Conduits .....solid yellow
Manholes, handholes, sewers, inlets and
house drains .....solid brown

A separate record is needed where manholes enclose mains. Where a foreign structure is being laid at the same time as a

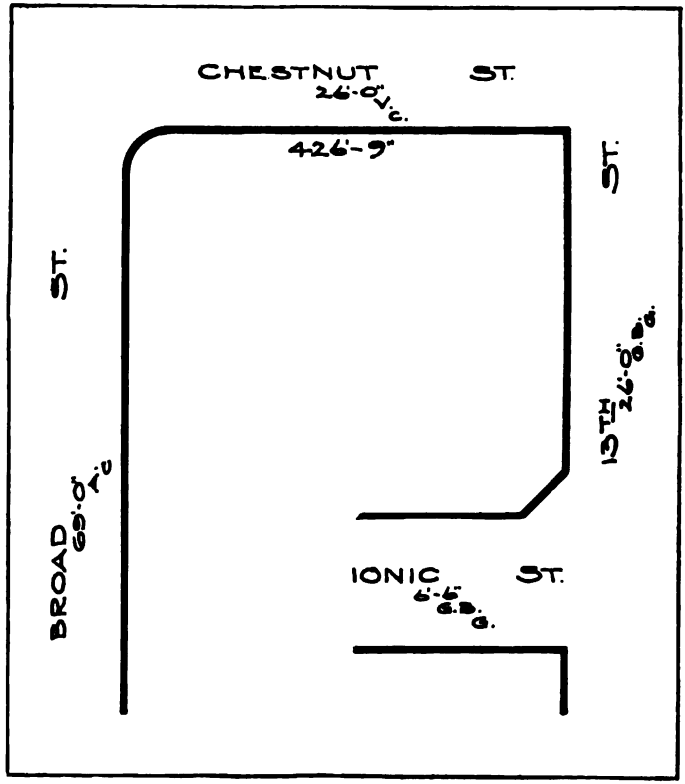

Fig. 32.—Designation of Curbs and Corners.

gas main, but is not actually in place when the main record is taken, its approximate location is shown by a dashed line of appropriate color. Clearances are shown in red and give the minimum distances between the main itself and also between a bell and any foreign structure.

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Curbs and corners as they exist at time of work are shown by a solid black line 1/32" wide, as in Fig. 32. Building and dimension lines, etc., are shown as in Fig. 33. Telegraph poles, lamp posts, fire plugs and pier lines, when needed as bases for location, are shown by conventional designs. Figures giving sizes, dimensions, covers, etc., are in black above the line indicating the main, the size being shown at right angles to the main to avoid confusion with dimension and location figures. Solid line rubber hand stamps are used to designate the various

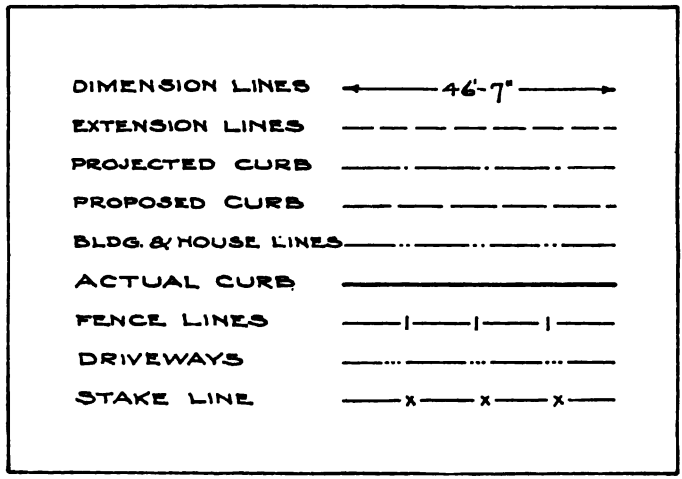

Fig. 33.—Building and Dimension Lines.

forms of bells and specials. Reducers are shown solid, tapered to indicate change in size.

When pipe or specials, are only partially exposed, the record indicates this. Under ordinary conditions, the street clerk does not leave in doubt the character of any special only partially uncovered, nor the relations between any intersecting mains.

Where a main is carried through the air, over or under a bridge, detailed information of its location is given. Where a new bridge is being laid, a working plan is always prepared

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before the work is begun, and the record made by the street clerk serves as a check against this plan, where the work is carried out as originally intended, or records any difference between execution and plan. Where an existing main is overhauled, and there is no satisfactory record of its location with relation to the bridge, the street clerk secures as detailed a record as may be consistent with safety.

Where pipe is laid above ground for temporary use only, but such use may extend over several months, a special record is made.

Where mains cross under steam railroad tracks, a plan is usually prepared in advance of the work, and the record as taken shows the relation between the tracks and the main, and serves as a check against the plan. In the case of street car tracks, a record of the tracks is not ordinarily taken where the main crosses at right angles, but is always taken where the main is under the track for some distance, as might be the case if the main lies parallel to the track, or crosses under switches.

For each job, in addition to the sketch record made out according to the foregoing rules, all the information needed for the sketch record card is filled out on the reverse of this card, which is shown in Fig. 34.

Of the information contained in the sketch record, there is transferred to the proper main chart only the size and general location of the main, using water colors for easily and quickly washing out, thereby preserving the surface of the chart. When these charts are on a scale no larger than 200 feet to the inch, it is a mistake to indicate on them any details as to specials except the use of fillets to denote connections. When the charts can be obtained on a scale of 50 feet to the inch, a fairly complete record may be made, but the same large scale that makes this detailed record possible allows such a small extent of territory to be shown on any one chart that experience shows the charts on a smaller scale are used for ascertaining the mains in any particular region, while the sketch records must usually be resorted to for certain necessary

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FORM 32 P. C. W. 3M-12 9-12

MAIN WORK SKETCH RECORD.

DISTRIBUTION DEPARTMENT
RECORDS DIVISION

REQ NO. ..... AMOUNT AUTH. .....

TOTAL PIPE LAID	PROGRESS REPORT	STRAIGHT PIPE ONLY	LENGTH CEM. LEAD
OF	OF	OF	
"	"	"	
"	"	"	
"	"	"	

TOTAL PIPE OVERHAULED "

OF "

" "

" "

PLOTTED ON CHART	MONTHLY REPORT	MAINS LAID REPORT	NO. FT.	RECORDED	A. & R. PIPE	BETTERED MAINS	COMPARED FOR NOTES	HIGHWAY SUPERV'S
NO. DATE			OLD	DATE	DRAFTSMAN	DRAFTSMAN		
INITIALS			NEW	INITIALS				

C. I. MATERIAL USED NO.

FOREMAN ..... CAULKERS ..... NO. .....

..... NO. ..... NO. ..... NO. .....

REMOVED .....

ABANDONED IN GROUND .....

JOINTS L..... C..... S..... PHOTO. NO. ..... ALBUM NO. .....

BUSINESS CLASSIFICATION ..... N. S. ..... A. S. L. ..... A. P. ..... A. R. ..... I. P. .....

NATURE OF WORK .....

.....

.....

.....

.....

RECEIVED, R. D. .....

..... STREET CLERK

PER ..... DUPLICATOR.

(OVER)

Fig. 34.—Sketch Record Card.

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details which even a scale of 50 feet to the inch cannot show, and therefore the limited use of such a chart does not warrant the expense of preparing it.

The sketch records for the work of the current month are filed until the end of the month in a special file. After the end of the month, when the monthly work has been properly recorded, the sketch records are transferred to the permanent file, where the arrangement is alphabetical by street names, all records for the same street being filed by street number. In order to make this filing by number possible, a hypothetical number is assigned to every record. Where the work involves only a street intersection, or an intersection and more or less work beyond the intersection in the direction in which the street is numbered, the hypothetical number assigned is the highest number belonging to the intersection on the proper side of the street. Where the work does not involve an intersection, or, if involving an intersection, extends beyond it in the opposite direction to the numbering, the number assigned is the lowest one belonging to any building, or lot, on the same side of the street as the work, and in front of which the work is done.

When a record embraces in part, or entirely, the same extent of main covered by a previous record, it is filed behind the earlier record. Where mains are frequently changed, it often happens that a true idea of the exact main location in any one block, or at any one intersection, can only be obtained by reference notes and by spreading out several sketch records made at various times, and noticing carefully how the later records make partial changes in the earlier ones. In this way the very state of affairs, *viz.*, great activity in the installation of underground structures, that renders advisable the adoption of the sketch record system, as opposed to the "blue print" record, previously described, because of the greater ease with which small changes may be shown by means of the sketch record, sometimes produces so many sketch records relating to one block, or intersection, that it becomes advisable to make

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what is called a "composite" record. This shows in one record, the block, or intersection, as it is at the time of making the record, and until the future brings new changes, the composite record is the only one that is consulted.

BRIDGE MAINS.

REASONS FOR BRIDGE MAINS.

Until recent years there were no bridges in territories provided with gas mains, except where such territory was divided by a body of water. In many instances, the stream spanned was navigable, and the resultant draw-bridge was of no use as a pipe support. Where the bridge was a fixed one, or where the approaches to a draw-bridge extended over a long stretch of land, marshy or otherwise unfavorable for main laying, in the former case, the whole bridge, and in the latter, the approaches, have been welcomed as a means of facilitating the conveyance of gas across the water.

With the growing abolition of grade crossings of steam railroads, within the limits of towns and cities, has come a great increase in bridges, of which a respectable proportion carry the street over the railroad. If it is necessary or desirable to convey gas across the railroad at any one of these bridges, the choice lies between crossing on the bridge, or laying under the tracks. The latter alternative is usually undesirable for several reasons, of which the two principal ones are as follows: First, the objection of the railroad company, which desires to reduce to a minimum any work by outside persons, in any way affecting the roadbed. If the right of way at the point of crossing is owned in fee simple, permission to cross will be given only on condition of removal on specified notice. This, of course, is not a condition that the gas company cares to accept. In every case the railroad must be held harmless for any damage resulting from the installation or presence of the main; second, the increased expense of installation and maintenance. As a rule, a crossing under the tracks will mean a long stretch of deep main on each side of the bridge, or else

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two vertical legs, each about twenty feet, either underground back of the abutment walls, or exposed on the side (usually) of these walls. Invariably the amount of pipe used and its depth will be greater than if the location is upon the bridge.

From what has already been said, it will be seen that the choice will generally be for the bridge crossing, whether over and obstacles, principally railroads, or over water. The disadvantages connected with a bridge main will be considered as the subject is developed.

LOCATION OF MAINS.

When installing a bridge main, the first point to be considered, viz., the necessary permission, is often inter-related with the second, the location. Bridges are generally owned by the public authorities, but sometimes the railroad is joint owner. Unless the addition of extra weight is considered dangerous, permission to lay is seldom refused, but the public authorities are often very much opposed to any location where the main will be in evidence. Generally such a prohibition means a location below the floor line, and entails extra expense in installation and in maintenance, and occasionally where the bridge is over railroad tracks, and the head room is limited, the railroad company interposes with the provision that this head room be not decreased in any way by the proposed main. The exact point at which any prescribed location becomes so disadvantageous as to prevent the bridge main altogether, will, of course, depend entirely upon local conditions. There are, however, some general principles as to location which apply universally.

Where the main girders carrying the bridge, also separate the roadway from the footway, a location on the top of such a girder is ideal. Next in point of desirability, would be on the bridge floor itself, in a corner of the roadway or (preferably) the footway. Blocks of concave top, fitting the main, should raise it one inch above girder, or floor, and a guard timber should protect a roadway floor main.

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If there is no location available above the floor line and within the bridge lines, laying along side of the bridge is usually preferable to laying underneath it. Often by attaching brackets to the outside girder, the main can be laid just outside the footway railing, with the bottom of the main about the floor level. If the girder carrying the footway, is deemed too light for additional weight, attachment may be made to the girder at the side of the roadway. This will bring the main under the footway.

There may be instances where the only possible location is under the main floor of the bridge. At the present time, most of the new metal bridges crossing over railroads are protected over their whole bottom from the action of the locomotive gases by a tight wooden sheathing. Only as a very last resort should a pipe be laid in between such sheathing and the bridge floor. So laid, it will at all times be most inaccessible for examination and painting, will be exposed to many corroding influences and escaping gas will be both hard to detect and a great source of danger, forming as it will an explosive mixture inside the sheathing. Where there is no sheathing the choice of location under the bridge will be determined by giving proper consideration to the various elements of first cost, maintenance cost, etc., that may enter into the case.

Where the location is under the bridge, provision should be made at time of installation, for a future means of ready inspection. This generally means building a platform under the pipe, or leaving hangers in which boards may readily be slipped at any time.

So far the types of bridges in mind have been those composed mainly of metal or wood. The advent of re-inforced concrete has brought the concrete arch bridge into the field. With it, location above the bridge floor, or along the bridge sides, is usually prohibited on the score of spoiling the artistic effect. Location under the bridge in the few cases where head room was sufficient, would mean a small stretch of main exposed in an inaccessible place, with most of the pipe buried in

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the sides of the bridge arch. This location also pre-supposes the laying of the pipe while the bridge is being built, for it is not probable that permission would be given to tear apart any existing bridge. In most cases, there should be no hesitation in letting the pipe be entirely built into the bridge, its location being usually as low as allowable without exposure on the underside of the arch, in order to avoid contact with the cinder base of the bridge surface. If a leak should develop at a pipe joint there is little chance of gas finding a way out through the concrete. In fact, in a concrete bridge, it is well worth considering where the length is great and the saving would be considerable, whether a cylindrical passage formed in the concrete would not suffice.

PROVISIONS FOR MAINS WHEN DESIGNING BRIDGE.

Except in discussing the concrete bridge, no distinction has been made between a bridge that has been built without any reference to the need for laying mains on it, and a bridge designed after ascertaining what necessary provision should be made for pipe crossings. There is little excuse for any company that allows the erection of a bridge, on which there is a present, or possible future need for a main, without making an attempt to have the location of the main previously settled. Probably in all large cities the official in charge of bridge work notifies the company of each bridge planned and asks them to state their needs as to pipe crossings, and to consult with him as to location. In any locality in default of such notice, it is very easy to have a knowledge of all proposed bridges.

Where the main location is to be alongside, or under the bridge, the work of laying can be greatly cheapened by suitable openings left in any masonry, and sometimes by holes drilled in, or brackets fastened to a girder, before it is put in place. A good plan in regard to the openings in masonry, is to have the specifications state that the contractor will place thimbles at places designated by the plan, these thimbles to be furnished by

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the company. In this way the company is bound to know where the thimbles are to be placed, and their cost is insignificant, consisting as they usually do of spigot pieces of cast iron pipe of a size just large enough to permit the insertion of the bell of the size of pipe being laid.

DESIGN OF MAINS.

MATERIAL.

Ordinary cast iron pipe with lead joints will probably need frequent re-caulking, due to vibration of wood or metal bridges, and also to temperature changes in exposed pipe. With cement joints in sizes 12″ or under, vibration would probably not cause leaks, but temperature changes probably would, and in larger sizes, both vibration and temperatures might be sources of trouble. Where cast iron is buried in a concrete bridge, it is perfectly satisfactory, but the thickness of the bridge at the arch crown may be so slight that the lesser diameter of a wrought iron joint, as compared with a cast iron bell, makes wrought iron pipe preferable for the concrete bridge, as it certainly is for the wood, or metal bridge. On the latter, the saving in space and weight afforded by wrought iron is quite desirable. Also, in the case of under floor locations, the fewer joints and lessened chances for leaks are important points.

JOINTS.

RUBBER.

For mains 6″, or under, in size, the ordinary form of screw coupling is advisable. For 8″ possibly, and for 12″ and over certainly, a rubber or asbestos joint with plain end pipe should be used. As compared with screw pipe, there will be a saving in first cost (always in labor and often in material) and in maintenance, for, as each joint acts as an expansion joint, temperature changes bring no strain on the line, and there should be no leaks.

SCREW.

Where screw joints are used, an expansion joint of some kind is advisable, one for one hundred feet of exposed

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pipe. Where there is only one expansion joint, it should be located in the centre of the line; where more than one, they should be equally spaced.

Each expansion joint should be firmly secured to the bridge, in order to prevent any chance of one joint taking up all the movement. At the ends of the line, where the wrought iron joins the cast iron, (usually just before the main goes underground) it is often easy so to locate the necessary specials, that any thrust or pull will be taken up by a swing joint effect.

SIZE.

The size of the bridge main is ordinarily that of the underground main on either side. However, in cold climates, it is probably a mistake to lay smaller than 4", and in many cases, smaller than 6". Also, if the region supplied is a growing one, or of large extent, the bridge main should be large enough to care for future growth, especially if the location is such that replacement would be difficult.

The above applies where the main is of moderate size, say 12" and under. Above 12", it might often be true that the size of the main very largely added to the expense of the job. If this is the case, it will often prove good practice to make the bridge main smaller than the pipe to which it connects. To what extent this diminution in size is advisable, will depend upon the special conditions in each case, one of the important factors being the length of the bridge, and another the demand for gas during the peak load.

One way of avoiding the use of very large pipe on a bridge, when the size in itself is the objection, is by laying two or more mains. A case in mind is where a concrete arch bridge was built over a single track steam railroad, well in advance of any development on the street which the bridge served, or in the general neighborhood. Future plans for the locality called for a 20" main on the street. When the city authorities asked what provisions should be made for a gas main, it was soon found that the minimum depth over the arch would not permit of

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larger than a 12″ wrought iron pipe. Neither could permission be obtained to lay alongside or on top of the bridge. To go under the railroad was not advisable. Therefore, the decision made was to bury two 12″ wrought iron pipes side by side in the concrete of the bridge. They, of course, will not give the capacity of a 20″, but the bridge is less than 80 feet in length, and the day when the 20″ capacity may be needed is so far ahead, that a third 12″ pipe did not seem justified.

Except where required for real, or assumed, artistic reasons, because of protection from gases of combustion, or because of severe cold, it is not advisable to enclose the main, but instead it should be painted with red lead, covered with a quiet color. A wrought iron pipe kept well painted is bound to be less conspicuous and take less room, than the same pipe boxed. A cast iron pipe with its large bells does not present a neat appearance. A box around the main on the floor, or side, of a bridge is a great collector of dirt, and corrosion will progress faster on a main covered by the ordinary box than if bare. Any covering over the pipe also renders any inspection much more difficult, and any escape of gas more dangerous. However, there are cases where at least a wooden shield under the main, to protect it from the direct impact of the gases from locomotive or boat stacks, is quite necessary.

As to the question of protection from cold, in the old days when a 6″ was a large main, a time honored rule was to make the pipe rising out of the ground, and going over the bridge at least a size larger than the underground pipe. In these days of large mains, it is safe to say that no such practice need be followed for latitudes south of New York City. In Philadelphia, the few cases of exposed mains stopped by frost have been confined to 3″ pipe. Where the climate is severe enough to warrant the enlarging of pipe, then also the question of protecting all exposed pipe needs to be considered. Whatever form of covering is adopted, great care should be exercised to make it water-tight, not only to keep the insulating efficiency high, but also to prevent corrosion. A good quality of canvas,

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kept well painted, will especially, when space is limited, form an excellent water-proof cover.

INSPECTION OF MAINS.

All bridge mains being more liable than the underground piping to injury from atmospheric and other external causes, should receive a periodical and careful inspection for condition, in addition to the prefunctory inspection given to them by the line-walker from time to time. This careful inspection should be at least yearly, and a good time is during the fall months, to ensure that everything will be all right for winter. The inspection will usually disclose the necessity for repainting, for minor repairs to platforms and coverings, and in the case of cast iron pipe may mean a resetting of many of the joints. Where pipe is exposed to the action of combustion gases, it is also well to attempt to form an idea of how fast corrosion may be proceeding. A 12″ cast iron pipe exposed under a bridge crossing many busy railroad tracks, was found on removal to have in many places less than ¼″ of metal left.

THE CHAIRMAN: Gentlemen, the paper is now open for discussion, and I trust we will have a very full and complete discussion. I would like to suggest when you rise to discuss the paper that you kindly give us your name so that we can make our records complete.

MR. J. D. SHATTUCK (Chester, Pa.): It is pretty hard to discuss a paper that is so well prepared in the first place. This paper presents good standard practice thoroughly and I want to comment only on one or two features:

First, cement joints. There is a feeling amongst many of us that cement joints are difficult to be made tight. I believe the tightness is largely a personal equation, varying in the size of pipe; 8 inches and under there is little trouble to make joints tight.

I put in one system of 27 miles of 8 inches and smaller 12 years ago and have never had a leak or break. I have a mile of 24 inches that has remained tight. Since this paper

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was written I have had a 16-inch line gone over carefully which was laid 10 years ago and found but few small leaks and these I do not believe would have caused damage to trees or would have reached the surface of the ground. I believe that cement joints can be made tight if the temperature of the joint is kept absolutely constant until the cement has taken its initial set. The larger the pipe the more necessary it is to maintain this constant temperature.

I am passing around a photograph taken of one joint which shows that the joint has pulled nearly one-quarter of an inch, strange to say this joint was found tight; the joint was apparently held by the cement soaked yarn.

Mr. Forstall describes the derrick that he has used in laying pipe. I designed a derrick illustrated in the American Gas Light Association *Proceedings* of 1898 that I believe is better for large work, it requires less labor. This derrick consists of 2 A frames built of angle iron with an I beam connecting them on which runs a trolley with a chain hoist. The derrick has a small roller under each leg. Planks are used under the derrick wheels alongside the trench. The derrick is easily moved and easily set up on the job, and after the pipe is rolled in position across the trench the derrick can readily pick it up and move it the entire length of 12 feet, which generally means that the pipe can be placed home without any shifting of the derrick. Three men can place the pipe; one man steering the pipe in front, another to operate the chain hoist, and the third entering spigot in the last bell, leaving the balance of the pipe gang to roll another pipe in position.

I would like to know if anybody has had any experience with tamping machines? There is a new machine which I have seen described recently and I understand it is being used with good results.

MR. G. I. VINCENT (Des Moines, Iowa): In the first place I would like to express my admiration of the general excellence of this paper and of the care that has been taken to include so much minute, yet important detail.

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On page 3 the division between large and small mains is admirable: that is, calling all 12-inch or under small, and 16-inch and over large. The differences between the laying of the small and large mains are very many and experience has shown that some division is necessary and the division suggested is undoubtedly the most satisfactory.

In the organization of the main laying gang, the time of one experienced man can be saved where piece work can be used in ditching. No supervision of the ditching is then required, except the laying out of the line and the inspection of the final ditch bottom.

Commenting on the service cart on page 11, I believe that the day of such heavy construction has gone by. A light cart constructed of very light galvanized steel angles and galvanized iron can be designed to take the place of the heavy cart. This will hold all tools required and is so light that even when loaded can be wheeled over unpaved streets by three men. The problem of transportation in the distribution of a gas company is very important, not only in its own first cost, but also through its intimate connection with all other work. This is particularly true in scattered territory. Anything we can do to facilitate transportation is an obvious advantage. Incidentally the small cart designed especially for its particular use and contents, allows no place for the accumulation of junk.

After considerable experimenting I have discarded the type of asphalt cutter shown "A" on page 16 and substituted for it the heavy, wide faced chisel held with special tongs and struck with heavy sledges. This method is as cheap as the asphalt cutter, makes a much narrower cut in the asphalt and avoids the flying chips. Particularly for small sections this method is useful as the cut is so small that it can be readily filled with cement when the piece of asphalt is laid back, and temporary paving results almost as good as new.

I would like to have seen in the paper more discussion of cutting through frozen ground. There is considerable litera-

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ture on methods of excavating through frost but I do not know of any best method. It is an important matter where excavations have to be made through four or five feet of frost.

Nothing is said of the best type of protection to be used in blasting, such as mattresses, heavy timbers or combinations.

The four-leg derrick, shown on page 28, is not as useful, I believe, as the three-leg type. Also there does not appear to be any ratchet or brake in the derrick, nor are the gears guarded to prevent fingers or hands from being caught. Also I believe that wheels are better than cranks for winding. Two light wagon wheels are satisfactory. Not only are they as easy to operate but they are far safer if the load gets away as there are no flying cranks to strike a man. They are also useful in transporting the derrick from place to place.

I would like very much to discuss the matter of blocking or no blocking but I believe that others will take up the question. However, I think the method described for settling the blocks by dropping the pipe on them is not entirely satisfactory, because of the uncertainty of the total settling effect.

No mention is made of wheel cutters for cutting cast iron pipe, both in the ditch and on the bank and if any one has had experience with these tools it would be interesting to bring it out.

In the schedule of main connections on page 35 cutouts and branch insertions are required when connecting 4-inch, 6-inch, and 8-inch mains to 16-inch. I believe that hub sleeves would be satisfactory for these connections and cheaper to install. Also I see no objection to tapping 20-inch and 24-inch pipe with a 3-inch hole and 30-inch pipe with a 4-inch hole to connect 4-inch mains. The short wrought iron piece can be adequately protected against corrosion.

On page 40, under "Placing Hat Flange," I do not think it is quite clear that stud bolts are used to fasten the flange to the main.

The suggestion to use gasoline to clean the bells I believe is

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objectionable as some gasoline leaves a greasy residue after evaporation.

I have experimented with the method of stuffing cement joints both with rubber gloves and with a trowel and I believe that the trowel is just as satisfactory and cheaper.

Referring again to blocking, pages 43, 63, etc., it seems to me that the answer to the whole matter is that small mains laid in original soil without blocking do not leak at the joints nor do they break in such a manner that would give the slightest indication that the break would not have happened if blocking had been used. This being true what possible advantage is there in using blocking on small mains.

On page 86 under "Loose Filling," no suggestion is made that filling can be satisfactorily done with a scraper either horse or motor drawn. One of the advantages of machine filling and tamping is that it reduces to some extent the number of laborers required on a job and as much of the gas main laying is done in the season when labor is most in demand, the reduction in the numerical strength of a gang would be an advantage even if there was no reduction in installation cost.

In regard to repaving, page 87, while of course different conditions arise in all towns, I have found that it is advisable to replace the base of all concrete base paving whether it is to be repaved by contract or by the company. The replacing of the concrete base is not difficult and gives an opportunity to make a temporary repair that will take the traffic until the permanent repair has been made.

The whole scheme of keeping records, page 91, described in the paper is certainly both ingenious and complete. The modification which I use in our city, which is one in which the general foreman looks after most of the street work including mains, services and repairs, follows Mr. Forstall's general scheme.

The form No. 11-D-M shown here is used for all street main laying and overhauling jobs. On the face of the

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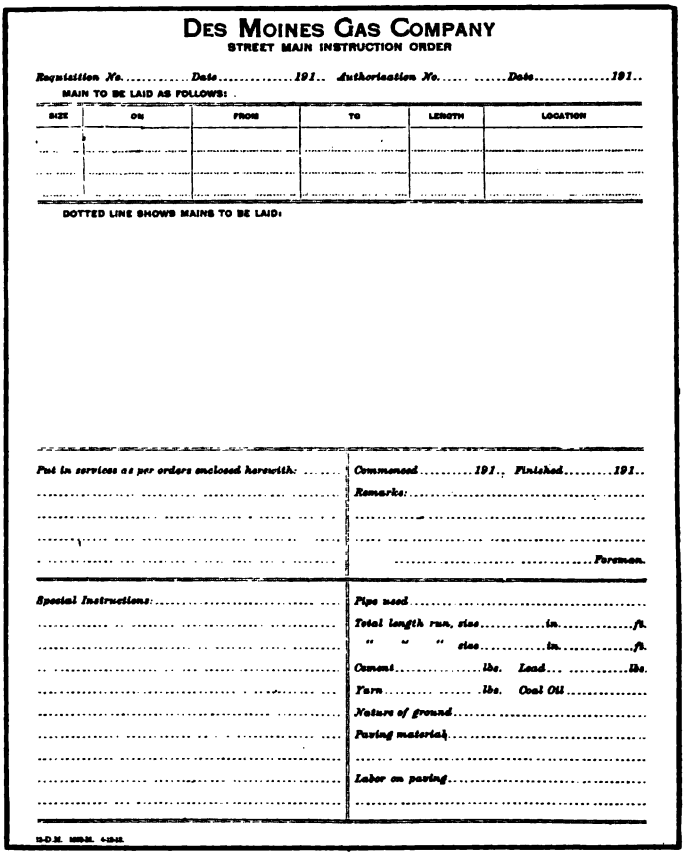
form all the data necessary for the foreman to have before starting to lay the main is given. After completing the job the foreman makes a detailed sketch of the work on the back of the form in the quadrille space, and also fills in the blank



DES MOINES GAS COMPANY

STREET MAIN INSTRUCTION ORDER

Requisition No. ..... Date ..... 191.. Authorization No. ..... Date ..... 191..

MAIN TO BE LAID AS FOLLOWS:

SIZE	ON	FROM	TO	LENGTH	LOCATION

DOTTED LINE SHOWS MAINS TO BE LAID.

Put in service as per orders enclosed herewith: .....

Commenced ..... 191.. Finished ..... 191..

Remarks: .....

Foreman.

Special Instructions: .....

Pipe used .....

Total length run, size ..... in. ..... ft.

" " " size ..... in. ..... ft.

Cement ..... lbs. Lead ..... lbs.

Yarn ..... lbs. Coal Oil .....

Nature of ground .....

Paving material .....

Labor on paving .....

11-D.M. 1000-11. 4-1911.

No. 11 D. M.

spaces on the face and back of the form. This forms the original record of the street main, but for convenience in record the sketch is copied into a sketch book and posted on a 500 foot scale map. A card index gives ready reference to

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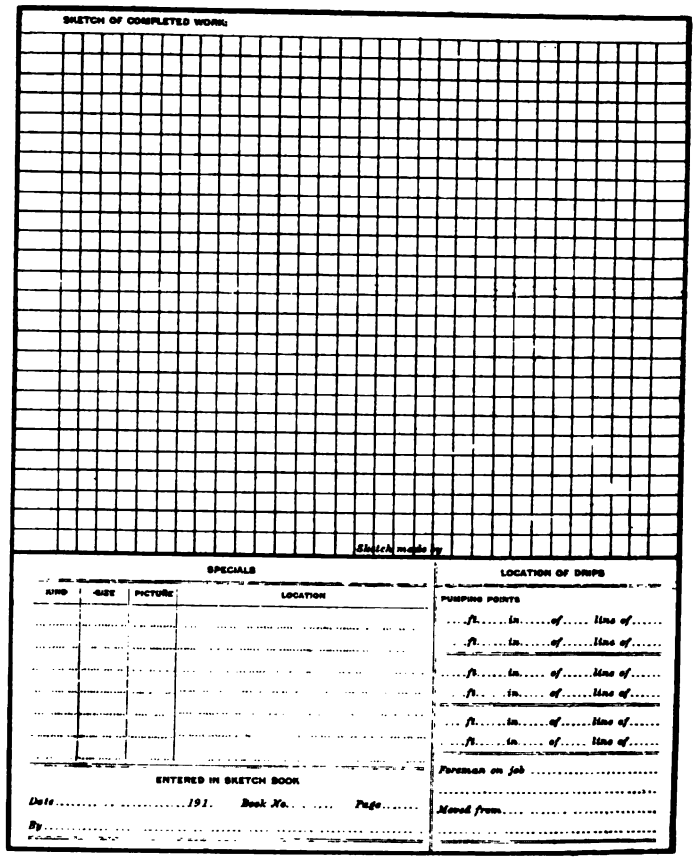
any sketch in the sketch book and the map gives the general locations of the mains.

One disadvantage not given of the concrete bridge is that the top of the arches being usually very near the street sur-


SKETCH OF COMPLETED WORK:
Sketch made by
SPECIALS
KIND
SIZE
PICTURE
LOCATION
ENTERED IN SKETCH BOOK
Date ..... 191.
Book No. ....
Page .....
By .....
LOCATION OF DRIPS
PUMPING POINTS
ft. ..... in. ..... of ..... line of .....
ft. ..... in. ..... of ..... line of .....
ft. ..... in. ..... of ..... line of .....
ft. ..... in. ..... of ..... line of .....
ft. ..... in. ..... of ..... line of .....
ft. ..... in. ..... of ..... line of .....
Foreman on job .....
Moved from .....

No. 11 D. M. Back.

face, therefore very little covering is left on the mains, so that stoppages by freezing may result. This disadvantage would be increased if several mains with decreased capacity were used instead of one larger one in order to get over the arches at all. The remedy is to arrange holes through which to dose the main

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with alcohol, but I believe the time is here when we must consider some positive method of dehydrating or treating the gas in the severe Winters that obtain in the Northern part of the country.

MR. A. H. HALL (New York): I owe an apology to Mr. Forstall in presuming to discuss his very able paper without sufficient study of its contents. I had believed that Mr. Simpson, the son of the father of Lead Wool, would have been here to assume the argument of the "defensive" position in which Mr. Forstall has placed all users of lead wool, but Mr. Simpson found it impossible to get to Richmond and I have therefore undertaken the task at rather short notice.

On page 59, Mr. Forstall estimates the cost of lead wool joints to be about 1½ times the cost of cast lead. It is probable that the labor item in this estimate is somewhat high for lead wool, as Mr. Forstall states that a complete set of caulking tools is used on each strand of lead driven. Experience has shown that one tool is all that should be used up to the last strand, when the joint is faced off smooth with as many tools as are necessary.

Assuming that a 6-inch cast lead joint costs complete, 50 cents, or about 4 cents per foot, a lead wool joint of the same size would cost 75 cents, or about 6 cents per foot. In the case of cement joints, I cannot make a close estimate, but from the statement on page 55, that five (5) men can make fifty (50) 6-inch joints per hour, I should think it would be fair to place the cost at 1 cent per foot for labor and material. This makes the relationship stand:

	Per foot
Cement	$0.01
Cast lead	0.04
Lead wool	0.06

In New York, in Manhattan and the Bronx, we use nothing but lead wool for all sizes. Pipe of this size (6-inch) laid under our ordinary conditions as to rock and pavement, costs us about $1.25 per foot. Under these conditions, the jointing cost per cent. of the total cost is as follows:

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	Cost per foot	Joint cost per foot
Cement	$1.20	0.8
Cast lead	1.23	3.3
Lead wool	1.25	4.0

Now with these figures before us, I believe Mr. Forstall has furnished all the defensive argument we need. He says on page 59, that even though lead wool has almost a zero leak record, yet for pipe 24-inch or smaller, the argument seems to favor cement.

From our experience in New York, I can go a little further than Mr. Forstall and say lead wool has a zero leak record where the caulking has been properly done, and further, that the joints may be subjected to considerable abuse through deflection, due to settlement, without showing leaks.

At the bottom of page 50, the tendency of pipe 8-inch and smaller to break under stress, due to settlement, when rigid cement joints are used, is noticed. This chance in New York is very real, owing to the constant disturbance of all sub-surface structures by new construction, as the telephone, telegraph, electric light and power wires are carried under ground in all of our streets, and in addition, we must look forward to the day when a great many of the streets will be tunnelled, near the surface, for rapid transit lines; all of our lines of main present the condition, where, to quote: "One leak might quickly fill conduits and manholes (and tunnels containing trains full of passengers) with explosive mixture." The parenthesis is mine. Mr. Forstall closes this paragraph with the following sentence: "For all the above reasons, therefore, lead joints are preferable in all special locations where future joint trouble is expected." In New York, we have all the conditions he mentions, but we do not expect trouble because we use a flexible joint which does not leak.

On page 51, the last sentence in the paragraph at the top of the page reads—"Ten years have shown a cement joint may leak after being tight for several years, and is then much more expensive to repair than a lead joint, but the saving in

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first cost is so great, especially in large mains, and the number of leaky joints so few, especially in small mains, that, as stated before, the user of the lead joints is put on the defensive." And in the next paragraph he says, "Where a good foundation may not be secured, lead joints may prove cheaper in the long run."

It should not require much of an argument to prove that in thickly populated centers at least, a company is justified in laying its mains in such a manner that the joints will not leak, rather than by following a method which has been proven to produce joints which may leak. Further, under conditions as they exist in New York at least, it is impossible to be at all sure the foundations upon which the mains are laid will remain firm for any length of time.

From the foregoing, I assume that Mr. Forstall admits the lead wool has some very decided advantages over cement as a jointing material, and that his condemnation of it is based entirely on the fact that it costs more.

In an earlier portion of this discussion, it was shown that the cost of labor and material for jointing in the case of 6-inch pipe with lead wool was 4 per cent. of the total cost of the completed line. I have checked this result in the case of 48-inch pipe, and find the same relationship to hold. With cement the cost figures 0.8 per cent., making the saving a little over 3 per cent. Like the majority of questions of this kind, the adoption of a policy can only be determined upon, after a careful study of the actual conditions surrounding each specific case. In New York where we are confronted by the practical certainty of injury to persons and property, by even a slight explosion; by the proximity of our mains to structures which afford spaces for the accumulation of explosive mixtures; by the frequency with which sub-surface construction of all kinds is undertaken in our streets, with the consequent disturbance of our mains; by the fact that we must subject a large number of our fellow citizens, the greater part of whom are also our patrons, to serious inconvenience every time we open the

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streets to repair leaks; by the difficulty of restoring our pavements to their original condition; all of these conditions make us feel that we need no defense for expending the extra 3 or 4 per cent. it costs us to employ a material which our experience has shown us to give a flexible joint which does not leak and which is, as far as we know, the best material obtainable irrespective of cost.

Except in this matter of joints where Mr. Forstall and I are not in very close agreement, I believe he has prepared one of the best papers on the subjct which has appeared in this country."

MR. G. T. MACBETH (Mt Vernon, N. Y.): We do not use any derricks for laying 16-inch pipe. We went to the expense of buying two kinds of derricks for a line of 16-inch pipe, but the derricks were not used. The men dropped the pipe into the trench with ropes. A gang of 10 men and one foreman had no trouble in laying from 40 to 60 lengths a day by just dropping them into the trench with ropes. In regard to the service carts, I agree with Mr. Vincent, that a lighter cart is better. There is also a point I do not think has been brought out, about using the derrick wheels, referred to by Mr. Vincent. By loosening the nuts on axle these wheels can also be used for transporting the derrick from one end of the job to the other without lifting or loading on wagons. I would like to emphasize Mr. Forstall's point on page 22 about laying out a certain section of the trench for each laborer. I find that there is great economy in this way in matching one man against another. By doing this, you can quickly get a line on the good men on the job and can weed the poor ones out very shortly.

In regard to leaving space at the end of the pipe for folding I find it is absolutely unnecessary to leave any space, provided you leave out 3 lengths for the fold instead of 2. We use hub sleeves of sizes recommended in the cast iron pipe standards of the American Gas Institute, and I agree with Mr. Vincent

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in regard to the hub sleeve as we find them very satisfactory.

One thing I think not yet touched on is electrolysis. We have had trouble with it on our pipes in the last 5 or 6 years. This trouble however, was confined to lead jointed mains. We found none on the cement jointed mains. To insure the insulating qualities of all the cement joints which we are using up to and including those on 12-inch pipe, we place a piece of rattan in the bell before shoving the pipe home. That entirely separates the end of the spigot from the inside of the bell and makes it practically a complete insulating joint as there is no metallic contact.

In the matter of cement joints on 16-inch and larger cast iron mains, would say that I have little faith in them for this reason: they are all right on low pressure or distribution pressure mains, but we never know when we want to increase this pressure, especially on these larger distribution mains, to pumping pressure. As soon as you get up to a pumping pressure, between 2 to 5 pounds, the cement joints, no matter how well made, will leak. I do not mean all of them, but at least one-third. We laid a line in 1906, and this year (1913) the street in which this pipe is located was taken over by the State. After State roads are established in New York it is rather hard to get a permit to open the street. Therefore we thought we would take great precautions on this line. We practically examined every joint for two and a half miles, and exactly one-third of the cement joints on that line leaked. We cut them out to a depth of an inch and a half and recaulked with lead wool.

Another interesting experience further down on this same line was that about 2 miles of 20-inch cast iron pipe with cast lead joints laid in 1900, showed absolutely no electric current being carried, although the trolley track was in rather bad shape. As these cast lead joints leaked we cut them all out and put lead wool in to a depth of one and a half inches after spreading the remaining part of the old cast lead joint in the bell by driving in a flat chisel. We found after this work was

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complete that the line carried a considerable amount of current. I do not remember the exact figures, but I know it was somewhere in the neighborhood of 5 amperes and a voltage of about 15 or 20 volts, which we consider rather serious. We then opened up that line and put in some insulating joints.

We also laid a few cement joints in 1910 on another branch of this 20-inch main, which carried about 3 pounds pressure at peak load and 12-inch the rest of the time. Every one of those cement joints which we put in for insulating purposes leaked in less than 3 years time.

When we laid our other 16-inch pumping line this year we did not put any 16-inch cement joints in it, but used for insulating purposes, flanged fiber joints having the bolts, washers, and the flanges themselves all insulated.

I think I might be able to give Mr. Shattuck a little information about that tamping machine. Mr. Simpson was talking to me the other day about using it on the repair gang work. He told me he put back the dirt at a cost of 20 cents a cubic yard with a tamping machine as against 40 cents for hand labor, and the beauty of the machine is that all of the dirt goes back into the trench. I thought this a very good recommendation.

I would like to hear something about working in frozen dirt. We have a great deal of trouble, and I have studied it to a certain extent with Mr. Simpson. In fact, he has gone to the trouble of designing a frost cutting machine, which, up to the present time has not been successful. I had about half a mile of 8-inch cast iron main to lay in frozen dirt about 3 years ago. Our orders were to lay it in a hurry. What I did was to blast the frozen dirt. Ordinary driving-bar, holes were put down and a trench was blasted, just as if we were going through rock. It worked out very satisfactorily, possibly because our fellows are so familiar with blasting as there is so much rock up our way. It may not work so well with men not accustomed to blasting.

I would also like to ask Mr. Vincent how he lays out his

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piece work on main laying jobs. It has been a hobby of mine for years, and I don't seem to be able to lay out specifications for trench work, so as to learn how much money each man is entitled to on the pay roll.

Another thing which we have found helpful in connection with locating mains not accurately shown in our old records, is what is known as the "Wireless Pipe Locator." It is a very simple device costing $65.00 There is one drawback to it however, and that is, if there are a lot of water heater connections in the neighborhood, you want to look out or you will land on top of the water pipe instead of the gas pipe.

Before closing, I should like to add a word or two regarding the paper. To my mind it has never been equalled. We can hand it to our foremen and tell them to read it like their Bible. The information contained in this paper was before now, only to be obtained through practical experience. I am sure that all of it has not been available in written form.

MR. A. GORDON KING (New York City): I was particularly interested in that section on page 50, where it was stated that 10 years have shown that cement joints may leak after having been tight for several years. It was my experience a few years ago to have to overhaul the main system of a town in the South, and the only way you could do it was to use the leakage detector, and in connection with that we used the device just mentioned, the wireless pipe-locator—except where there was electrolysis in the mains—and the majority of the leakages were on cement joints. The lead joints seemed to be tight, but we had no method of knowing whether the men who put those cement joints in in the first place were experienced men, and whether their joints would have held, had they been well done. Presumably with colored labor and inefficient supervision they were badly done, and they were very difficult to find and very hard to cut out.

I notice the question of blasting is discussed. We always used the ordinary railway ties with bagging over them, but I

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saw in one of the technical journals a little wrinkle we never tried, but which I think would be good *viz.* chaining the ties together, for in case of their flying up they would simply raise and not break away. I heard of one experience, where a piece of a tie had gone clear through a window and injured someone in the house.

MR. J. D. VON MAUR (St. Louis): I did not know that there was so much to be said about this laying of cast iron mains. There seems to be a whole lot. I understood the papers were to cover the various subjects, but the discussion seems to be going over on subjects that are being touched upon by the other papers. When Mr. Forstall's paper first appeared in the *Gas Institute News,* I went through it very carefully and urged all of our District Superintendents and various foremen to read it over carefully also.

It might be well to caution younger men to bear in mind that it is not a paper on 'Distribution,' but simply a description of the methods advocated by the author for laying gas mains. It is also well to remember that the methods described are those pertaining to the City of Philadelphia. The first impression on reading the paper, is that there is too much of what might be called elementary detail in the description. This paper is a very difficult one to discuss in detail. It must be constantly borne in mind that the soil and underground conditions, as well as surface conditions, such as width of streets, as well as questions of policy and different plans of organization of a gas company would change very vitally the methods which would bring about the best results.

Our soil conditions are very different from those in Philadelphia. The bulk of our soil is composed of a yellow clay, and our method is to lay the pipe so that the tops of the blocks will be flush with the bottom of the trench, so that the pipe, when laid, lies on the undisturbed bottom of the trench as well as on the blocks. I have been told many times that this is impossible to do in practice, but I know differently. Our pipe is laid so as to have a practically perfect foundation, and it is to

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the lack of such a foundation that I attribute the trouble many companies are having with leaky joints. We have practically no leaking joints in St. Louis on low-pressure mains, and practically none on high-pressure mains under 16 inches in diameter, and very few on the high-pressure mains larger than this size.

In this connection I am reminded of a meeting which occurred in Philadelphia in 1898, when I was connected with the United Gas Improvement Company. Mr. W. J. Serrill, Engineer of Distribution, called a meeting of the men having charge of the various main laying operations, and the question, "What is the best method of forming the foundation of the pipe," was under discussion. Mr. Serrill contended that theoretically at least, the best results would be obtained if the pipes were laid on a solid, undisturbed bottom. Without exception, all of the other men present, including Mr. Forstall, Mr. Rosenthal and the speaker, contended that the proper way was to place the pipe on blocks, at the bottom of the trench, and then thoroughly tamp the earth under the pipe. My experience has demonstrated that every man present was wrong, with the single exception of Mr. Serrill.

We make no attempt to keep gangs of men working every month of the entire year.

During the winter months we get our information relative to the streets which will probably be paved during the coming season. We arrange to have sufficient pipe and specials in our store yard to take care of our work at all times. As soon as the weather conditions permit, we proceed to take care of the streets ahead of paving first. Owing to the fact that a large number of our streets are not on grade, this work constitutes the most important part of our operations, as great economies can be affected by working in conjunction with the various contractors and city officials. As soon as this work is well under way, we proceed to take care of new mains for consumers, and endeavor to get this part of the work completed as early as possible, usually by August, in

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order to get the benefit of the new business, and to give the Commercial Department an opportunity to get all of the consumers using gas before cold weather sets in. In the meantime we make arrangements to lay such distribution mains as are laid out for the year's work, and when this work is completed the gangs are cut down to a minimum. The balance of the year is used to take care of special work of various kinds which needs to be taken care of. This requires a very small force.

Our main effort is to train our individual foremen as to the reasons why certain methods of doing work will result in a minimum cost of maintenance. In the final analysis it will be found that it is to the foremen on the street to whom we must look for results. The Engineer or Superintendent who can best train these men and win their confidence and respect will be most valuable to his company.

I wish to emphasize the fact that while there are certain fundamental principles which will govern the entire work, yet owing to the great diversity of conditions in various cities, the details of carrying on the work will differ widely. What may be good practice in one city may not prove economical, or even desirable in another. For instance in the delivery of materials. —We have proven to our own satisfaction that while it is unwise to carry a large stock of pipe or specials in the storeyard, it is not safe to trust to the pipe foundry and railroads to have pipe shipments arrive in such a manner that it can be delivered on the work, though desirable as that might be. Every piece of material left on the street is a chance for an accident until it is used and placed in its final resting place. We, therefore, deliver our small pipe on the job a day or so in advance of actual operations. Our pipe is delivered in cars to the storeyard, and loaded from the car to the yard, or from the cars direct to automobile trucks by means of a hand-operated loading machine. We find this much more economical than having the cars consigned to various switching points and unloading by hand. Of course in the case of large size mains

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we deliver direct to the job when the conditions are such as to make this plan advisable.

As to separating materials taken from the trench, conditions again would determine very largely how this should be done. In St. Louis, for instance, concrete taken out of the trench under the pavement cannot again be used, except for filling in. (City Rule). Under these circumstances there would be no great necessity of using care in keeping the concrete from being mixed up with the earth taken from the trench. Taking up paving is another detail which will vary in different cities. Where the bricks are grouted in with cement, as they are in St. Louis, it would be impossible to take up the paving in the manner described by Mr. Forstall.

The method of making joints is now practically uniform. There is still a difference of opinion as to which material is the best for the purpose. All our joints, for all sizes of pipe, are made with cement. The only real trouble we have had is where we changed from Dyckerhoff to a domestic cement. In this connection I can only emphasize the fact that too much attention cannot be given to the foundation under the pipe. With a practically perfect foundation, and joints made with Dyckerhoff cement, there ought to be very little trouble. We did not have a single leaking cement joint in 12 months, and only 12 leaking lead joints.

The number of joints caulked per hour or per day is not material. Mr. Forstall says on page 55, "A gang of 5 experienced men can make 50 6-inch joints per hour." This would mean 600 feet of main per hour. By actual test, I find that a joint can be made in 3 minutes, but we have never attempted to lay pipe at such a rate. The quicker men forget that the main thing to accomplish is to lay a large number of feet of pipe per day, and remember that a little less in quantity and a great deal more in quality is what they should strive for, the better will be the result of their efforts in the last analysis.

In making cement joints we pay very little attention to temperature conditions, except in very large size pipes. One

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of the best lines of 24-inch high-pressure main which we have laid, and one on which we have never had any difficulty, was laid in the middle of winter, with the thermometer below freezing. Salt water was used.

As to lead wool, it has a large useful and increasing field, but as yet no one has been able to show us that there would be any advantage in making the change in St. Louis.

As for testing joints, it is a good plan for the Superintendent to occasionally order an excessive pressure put on the pipes when the foreman is not expecting that such a test will be made. If the results are satisfactory under these conditions. it can be assumed that the general run of the work is satisfactory.

Gauge readings are, at best, a very poor guide. The longer and larger the line of pipe to be tested, the less reliable the gauge becomes. A moment's thought will emphasize this fact, as the greater the volume in the pipe to be tested, the smaller will be the effect on the gauge, for any given escape of air. The gauge is an old method for testing pipe, but the greatest dependence should be placed on actual inspection with soap-suds, and on a careful supervision of the manner in which the work is done. For large sizes of pipe a gasoline engine and compressor mounted on a truck will prove satisfactory.

As to refilling trenches, the methods employed will vary materially with the class of material encountered. Clay will expand 30 to 40 per cent. on loosening, and under certain conditions of moisture it will be found extremely difficult to get all of the earth back into the trench. I am in hopes that the tamping machine now on the market will be so strengthened and modified as to make it a practical tool for this work, especially on streets where there is a pavement. These improvements in the machine are now being made. It is of the greatest importance to so fill the trench that the paving will not settle, especially in cities where all of the paving is on a heavy bed of concrete, and where the bricks, etc., are grouted in place. Under certain soil conditions it takes a considerable

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time after a trench is flushed before it is in a condition to permit of paving, so that if flushing is used on paved streets located on clay soil it would mean that the street would be kept in a torn-up condition for several days. This is something we make every endeavor to avoid, as we find that people do not object to the tearing up of a street, provided the dirt is replaced and street put in condition promptly.

Referring to field notes, I believe there is such a thing as going into too great detail, at the same time accurate notes should be taken of all underground work, although the location of each joint I do not consider so important. I know of cases where mains have been barred for leaks—dependence was placed on the field notes—and it developed subsequently that the bar holes were being placed over the center of the pipe. Neither do I see the need of the surveyor's report, shown on page 95. It might be all right on a very large construction job, but under ordinary conditions where there is proper supervision, I see no need of such a report, except a certain amount of gratification that it gives to the main office force. The need of accurate notes increases with the complexity of the work. New work should be placed close to the curb, where possible, as in this position it will be less liable to interference. Of course with reference to drip pots, valves, etc., a most careful record should be turned in and should be again checked at the main office.

If Mr. Forstall's paper is read carefully, bearing in mind that it is simply a description of Philadelphia practice, it will be of considerable value to the reader, but the reader must remember that the differing conditions may be the deciding factor as to methods employed. There are important problems coming up every day, and these can rarely be decided from what one has read. It takes a large amount of experience, a whole lot of "gumption," and a lot of common sense to work out the best practical solution in any difficult problem that may come up. My only regret is that Mr. Forstall did not omit some of the more elementary detail, and discuss some

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of the general distribution problems, which are very much in need of solution and which he is so well fitted to discuss.

THE CHAIRMAN: Now, there has been a lot of discussion on cement joints, and things of that nature. I do not know whether you want them discussed now or want to let them come up in the natural course of the other papers. Would you suggest having them come up now at this time?

MR. WALTON FORSTALL (Philadelphia): I think Mr. Vincent's paper is a pretty good chance to talk about cement joints, as I remember.

MR. J. D. VON MAUR (St. Louis): Someone asked about cast iron pipe cutters. I arranged sometime ago to have the Manufacturer send me one of these cutters for a 10 days' trial. The cutter arrived and was sent on the street and tried. The foreman condemned it. Unfortunately, it was returned to the manufacturer before I had an opportunity to examine it personally. We therefore arranged to make a new test, but in the meantime our City Water Department made a number of experiments in cutting out 10-inch, 12-inch and 16-inch pipe. They made a cut through a 16-inch pipe, I believe, in 26 minutes, and the work was done very nicely indeed. I believe it is a good tool, and when properly used will do away with the not infrequent uneven cuts. It is, of course, possible to make an even cut in the usual method with diamond points and dog chisels, but if a foreman cuts out, we will say, a 24-inch main, for instance, and the cut is not quite square with the axis of the pipe, he frequently accepts the cut, rather than to make a recut of the large main.

All of these new appliances should receive encouragement from gas companies, as this is the only way that progress can be made.

Regarding the derrick which Mr. Vincent referred to, I would say that I consider the standard three-legged derrick positively dangerous. The question as to the best derrick to use depends very largely on where you are using it. I think

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the derrick Mr. Forstall uses, which is almost identical with the one used in St. Louis, is a very practical tool for city conditions. We use the large wagon wheel in preference tc the crank. The derrick that Mr. Shattuck uses is probably best adapted for his conditions.

MR. C. H. WARING (Kansas City, Kansas): One point that has not been brought out. We have not used the tamping machine ourselves, but the Bell Telephone Company in Kansas City have used it with very great success. One of the best features about it is in cutting asphalt. They have a tool that cuts on both sides of the trench at the same time. It will cut asphalt very rapidly. In cutters for cast iron pipes, I want to say we have used them with very great success.

MR. G. T. MACBETH (Mt. Vernon, N. Y.): If you use a tamping machine to cut asphalt, why cannot we use it to cut frost? Mr. von Maur said that a great many people have changed over from Dyckerhoff to domestic cement. We have not done it and do not intend to. We still think the Dyckerhoff is the best and will stick to it.

With regard to the tamping machine, I understand that the Ingersoll-Rand Co. are getting out a tamping machine that might be interesting to the people who are looking for such a machine. Wedges as mentioned on page 27 in Mr. Forstall's paper, are left in by us and are not removed after the pipe is anchored. Mr. von Maur referred to the occasional use of excessive pressure to determine whether the work on the joints was being properly done. I do not know exactly what he meant, but we test all distribution mains with air at from 10 inches to 20 inches of mercury. In addition, we go over the joints with soapsuds while the pressure is on. When laying what we call transmission mains, we test them with 10 pounds air pressure before filling in and go over every joint with soupsuds. We found joints absolutely tight at 10 pounds, that leaked when we put on 20 pounds.

People living in the neighborhood of cotton mills will find, I

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think, old carding cloth very economical, more so than regular wire brushes.

We have used two kinds of cast iron pipe cutters. I do not know just now the names of them. One was condemned by the foreman, as Mr. von Maur says; the other works satisfactorily. I cannot tell you which is which.

THE CHAIRMAN: Is there any other discussion on this paper? If not I think we will call upon Mr. Forstall to close the discussion.

MR. WALTON FORSTALL (Philadelphia): The discussion, with its diversity of views has been very acceptable because, as Mr. von Maur has said, my paper must largely represent the local standpoint. I tried to make clear that it treated of only one thing, and was not in any way a treatise on distribution. It was written in great detail and made very elementary because I thought there was a field for such a paper. Of course, this may be a mistake; also, no one can learn the art of main laying from a book. If any one should read this paper and then try to lay a main without any more information, he would certainly fail. The paper is only of value as supplemented by actual street experience.

There were many points in the discussion that I would like to touch on if we had more time. I want, however, to state very clearly my position with regard to lead wool. In the paper I said little about lead wool, not because I am in any way opposed to its use, but solely because I know very little about it. Our Philadelphia conditions do not seem to require its extensive use. I can see, however, that under New York conditions lead wool might be just the thing to be used. It is quite possible that when we know more about large cement joints in Philadelphia, we will use less cement and more lead wool. We are in a waiting attitude just now. The tightness of cement joints seems to depend largely on the men who made the joints. As for the same size pipe and for the same length of life, we have some lines of large mains made with cement joints, that have been very tight, and on the other hand

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some on which there have been a great number of leaks. As far as small mains are concerned, we have laid over 400 miles with cement joints, and have not had more than 20 leaks in that distance. With this record, and with the protection that cement joints seems to furnish us against electrolysis, it seems undoubtedly the material to use for small pipe. As to its cost, the average cost per foot of our 6-inch pipe, most of it laid in unpaved streets, is about 60 cents, and the cost of a cement joint about 7 cents, a little more than half a cent a foot. Consequently, the ratio of joint cost to the total main laying cost is not the same for Philadelphia as for New York.

I am not at all sure that cement joint leaks are only due to settling. We have laid some 30-inch mains on concrete blocks, yet have had leaks in their cement joints.

MR. C. H. WARING (Kansas City, Kan.): This paper is so valuable and the discussion so valuable that I think it should be used as a text book, and I therefore make this motion, that we refer to the incoming board the suggestion that the paper be published in pamphlet form with discussions as an appendix, so it will be available for sale.

(The motion was duly seconded and carried unanimously).

On motion duly made and seconded it was decided to combine Mr. Rice's and Mr. Vincent's papers and discuss them simultaneously, and to do the same in regard to the papers of Mr. Simpson and Mr. Gould.

THE CHAIRMAN: Mr. Rice will now present his paper.

Mr. H. L. Rice then presented his paper on the Installation of Mains and Pipe Lines of Steel and Wrought Iron.

THE INSTALLATION OF MAINS AND PIPE LINES OF STEEL AND WROUGHT IRON.

Abstract.—The cases in which steel or wrought iron may be profitably substituted for cast iron may be stated as follows: In systems

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operating under pressure exceeding 5 pounds to the square inch; for 2 and 3-inch low pressure mains when these sizes are suitable; occasionally for 4-inch low pressure mains during periods of high priced cast iron pipe; and in instances where organizations are not well equipped for handling cast iron work at reasonable prices.

The question of wrought iron as against steel seems to come down to the relative corrosion, and the concensus of opinion of a number of authorities quoted seems to be that there is little or nothing to choose between the two, although one points out that hand-puddled iron stands much more chance of being uniform and therefore free from corrosion than steel made from scrap largely by mechanical methods.

On account of the susceptibility of both wrought iron and steel to corrosion, they are dependent for maximum efficiency upon protective coatings. Pipe for use within a limited distribution area is usually coated at a central point where heat is available. All mill scale and rust should be cleaned off the surface before applying the coating, and the utmost care should be taken afterwards to prevent the coating from being knocked off or rubbed off. It is in this respect that the additional protection of cloth or paper wrapping is of particular value, and when the soil is bad or electrolysis feared, this extra protection should be used. For unusually severe conditions heavily pitching the pipe in a wooden trough is of special value. Where the pipe is received at outlying stations and transportation is difficult, coating on the job is preferable.

The organization for laying wrought iron pipe in a small town is much simpler than for laying cast iron. Any competent service man or fitter can be entrusted with this work, subject to the usual oversight of the superintendent or general foreman.

The organization for laying a long country line is of more special and particular importance. Special arrangements are necessary for unloading and stringing the pipe for coating (it will be found better in work of this character to coat the pipe after distribution), for housing, feeding and transporting the men, transportation of material, and for the actual organization.

The force should be divided into plowers, diggers, pipe layers, recoating and testing men and ditch fillers, the number in each gang depending upon the nature of the soil, size and speed of other gangs, etc. For filling a winged plow is used, followed by a road grader.

The possibilities of digging machines are of interest to distribution engineers, especially in cross country lines. These machines do away with the plowing and digging gangs, making the organization much smaller and simpler. The machine must be light and narrow, well constructed, must be able to operate on a wide range of fuels, must

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travel at a fairly high rate of speed, should throw dirt to either side of the trench at will, and, finally, must work cheaply. A machine used under the writer's supervision and costing $3,000 is of the endless chain bucket type, driven by a 25- horse-power gasolene engine, and cuts a trench from 18 to 28 inches wide and any depth to 10 feet at a rate of from 1 to 5 feet a minute according to the width and depth of the trench and nature of the soil. As an example of the working of the machine, an instance is given in which, in 11 actual working days, 11,808 feet were excavated at a cost of 1.02 cents per foot, including wages of operator and assistant, board bill of operator, some teaming, gasolene, lubricants, and a few minor repairs. The digging was through a wet, sticky clay, some gravel, and with a few rocks, roots of trees, etc. The ditch was 24 inches wide and 4 feet deep.

The trench for screw pipe is made of uniform width throughout. Where the pipe is screwed up on top and afterwards lowered into the trench, a ditch as narrow as 12 inches may be found satisfactory. The usual practice in city work is to joint all pipe in the trench and block carefully, using stones if cheaper and more convenient. Pipe should be ordered with loose couplings, and the greatest care should be used in cleaning the threads and jointing. In high-pressure work the question of exact grade is not of as great importance as in low pressure since the moisture is all removed in the first mile of pipe. Opinions differ as to the relative advantage of jointing high pressure in the ditch or on the bank, but practice is often governed by conditions. High pressure mains are preferably tested with gas at a pressure exceeding the maximum which the piping will be called upon to stand; where gas is not available, air may be used.

The choice of fittings in low pressure work lies between malleable, cast iron and slip fittings, and for high pressure between extra heavy cast iron, slip and, in the smaller sizes, galvanized. Cast iron is more trustworthy than malleable, but should always be extra heavy. All except slip fittings should be tested as to tightness before installing. Slip fittings are convenient and provide for expansion, but are objectionable in regard to life of gaskets and difficulty of renewals. Rubber gaskets have been found to be in perfect condition after years, and, on the other hand, have been found in other cases to deteriorate very rapidly. The failures are due largely to abrasion caused by motion of the pipe, and occasionally by chemical action of the soil and the gas. One manufacturer has placed on the market two types of rubber gasket designed to resist abrasion, one tipped with duck and the other with lead, but sufficient time has not elapsed to determine the value of these. Another manufacturer has brought out an asbestos gasket which is also under observation. Where the pipe is dead-ended, the slip joints must be anchored. Slip joints should also be used on each side of every

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iron fitting to take up the strains on long pipe lines. They are also of great convenience in filling gaps and cutting in fittings, the only objection being the question of life of gasket. This is of special importance under pavements.

The following will be found good practice: Low pressure town systems: Cast iron, standard weight screw fittings; one slip joint sleeve for each 400-foot block or less. High pressure town systems: Extra heavy cast iron or slip joint fittings at intersections; one slip joint in close proximity to each valve. Pipe lines: Pipe to be bent where possible instead of using ells. Extra heavy fittings only should be used. Slip joints are preferable for tees and crosses except where an opening is dead-ended; all fittings protected by slip joint sleeves on each side, and other slip joints installed in the line at intervals, but not to be called upon to relieve strains unless installed as close as 200 feet apart.

As there is no occasion to use valves in low pressure, what follows applies to high pressure only. General practice is to place valves at half mile intervals, but on account of trouble experienced by deposits on the seats, one large system changed from single valves every half mile to two valves about 10 feet apart at intervals of a mile. The town system should be carefully districted, this being facilitated by the fact that in high pressure work dead ends are not objectionable. Arrangements should be made, also, so that any valve can be shut off without a moment's loss of time.

High pressure mains must receive the same protection from cold as low pressure to preserve the candle-power, and should, therefore, be carefully protected at all exposed places. One danger is that in warm periods in winter the ice forming inside the pipe in such places will fall off and form slush in the pipe, possibly stopping it at some point difficult of access.

Where two or more cities are supplied from one pipe line, it is best to place a reducing governor at the entrance to each town, thus making the town pressure independent of the pipe line pressure. The simplest construction only is required, and operation within one pound is satisfactory.

Steel pipe of 8-inch and larger is manufactured in different weights, and there are, also, grades of tubing and casing in which the thickness is still further reduced. Pipe lighter than standard weights is often used, screw ends being employed for 8 and 10-inch, and couplings of the Dresser type for larger sizes. This is particularly the case in natural gas practice.

All moisture should be removed from high pressure gas as soon as possible, which is most conveniently done by employing baffle plates.

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If the line itself is used as a condenser, the baffles should be at the low points within the first two miles. If the gas is cooled at the pumping station, baffle tanks at this point will remove the greater part of the moisture. The pipe up to the last baffle should be laid below frost if possible.

Choice of Pipe.

Screw Joint Pipe vs. Cast Iron.

In the choice of pipe for mains and pipe lines the following conditions must be considered.

1. *Suitability.*

Cast iron pipe is not suitable for high pressure work, for pressures exceeding 5 pounds, nor for low pressure work in sizes under 4 inches, in the first place because of its porosity and the uncertainty of the joints, and in the second place because of its brittleness. Screw joint pipe of wrought iron or steel, because of its shorter life, is particularly less suitable than cast iron in certain locations. Such locations may be those where streets are shortly to be paved, and the cost of replacement thus largely increased, or locations where soil and electrolytic conditions are especially unfavorable.

2. *First Cost of Material.*

Screw joint pipe is frequently cheaper than cast iron in the smaller sizes. Relative price conditions change materially from year to year, and will always be closely followed by the careful builder. Where sizes smaller than 4 inches are sufficient, the first cost of screw joint pipe will invariably be found cheaper than the first cost of the smallest available size of cast iron pipe, namely 4 inches.

3. *Cost of Installation and Maintenance.*

This consideration may go deeper than cost and include in small organizations the ability to install first-class work using cast iron material. Small organizations frequently report leakage less, and maintenance easier and better, when dealing with screw joint pipe.

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The proper decision will be that which, estimating the various conditions accurately, resolves them finally in terms of ultimate yearly cost, including, as already suggested, depreciation and also including interest on the investment.

The possibility thus exists that screw joint pipe may profitably displace cast iron for low pressure work in the following cases.

1. Where pipe smaller than 4 inches is sufficient for the locality with the usual reasonable provision for the future.

2. Where the first cost of screw joint pipe 4 inches or larger is less than that of cast iron. There is sufficient differential frequently in 4 inches to merit consideration, and occasionally this differential has extended to 6 inches, while in larger sizes cast iron has generally been cheaper.

3. Where in small organizations screw pipe can be laid and maintained cheaper, better and more readily, because of the absence of a regular crew skilled in and equipped for laying cast iron pipe.

4. Where special elements of depreciation are anticipated; such as the condition where the future development of a locality is doubtful and long life of pipe is of less consequence than present service at the lowest first cost, or when a larger feeder is planned for the future, and the cheapest temporary provision is desired from the existing system at distant intervals.

The consideration of interest and depreciation is of the utmost importance as may be illustrated by taking an extreme case. Let us assume the life of cast iron pipe as unlimited, and steel pipe 40 years. This is purely arbitrary and expresses no opinion on a subject in which soil and electrolytic conditions are all important. In case 1, if a 3 inch steel pipe, costing say $315 for 1,000 feet laid will serve, and a 4 inch pipe, the only alternative in cast iron, costs $425, the money saved by the use of 3 inch, $110, will at 5 per cent. compound interest, amount to $291 in 20 years, $475 in 30 years and $774 in

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40 years. The saving arising from the original choice of 3 inch is therefore considerable, if during the period, the expectations as to the locality and its gas consumption are reasonably realized, and if the expected life of the main is approximately experienced. Unexpected changes in general distribution conditions during the period may make the saving less or greater, according to their character and extent, and other unforeseen contingencies, such as pavement, change of grade or location, may cause a material change in the final figures. Naturally, however, determinations can only deal with a reasonable estimate of the future, and variations over any considerable territory will doubtless be found to average.

The drift of engineering opinion is naturally toward the use of cast iron for underground work and the burden of proof for consideration rests upon the pipe of shorter life.

The case for steel or wrought iron pipe may, however, be stated thus:

In high pressure systems, it is the only suitable pipe for pressures above 5 pounds. In low pressure systems, use will be found for it:

Continually for 2 inch and 3 inch mains when these sizes are indicated, after careful consideration, as proper for permanent need, or for some desired temporary service.

Occasionally for 4 inch mains during periods of high priced cast iron pipe, or in organizations not equipped for laying and maintaining cast iron at reasonable cost.

Seldom for 6 inch under the same conditions.

Choice of Screw Pipe.

Steel vs. Wrought Iron.

In the choice of screw joint main pipe, as between wrought iron and steel, the gas engineer meets the same problem that has confronted him for years in his service pipes, with the additional qualification that tensile strength is an important consideration in pipe line work. The effect of expansion and

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contraction is especially severe on long screw joint pipe lines which frequently stretch for many miles without bends. It is now well known that expansion sleeves at intervals are but a doubtful safeguard. Lying occasionally in frozen ground, or in soil that becomes unexpectedly hard packed, the strain, even with a carefully planned expansion sleeve protection, often becomes very severe. There is in fact a difference in opinion among high pressure engineers today as to whether sleeve protection can be sufficiently well planned to warrant its use in screw joint work. Two large companies are known to lay all their pipe lines without the use of expansion sleeves. The Western United Gas and Electric Company laid 9 miles of 8 inch line in 1910 without sleeves, to test this proposition. Two breaks occurred in this line the first year; in both cases the line pulled apart in the body of a valve, separating 2 inches. The valves and fittings were then protected by sleeves. One more break followed, this time in a coupling. Two years have since passed without any additional breaks. This breakage is no more severe than has occurred in other lines of this company laid with sleeves. Thus on 18 miles of 8 inch, laid in 1912, with expansion sleeves every 800 feet, there have been two breaks caused by pulling apart, one at a valve and one at a coupling. The practice of this company originally was to install an expansion sleeve every 500 feet, and at present it is installing them every 1,000 feet. This practice is based on the conclusion that sleeve protection, unless sleeves are used at nearly every joint, is only partially dependable, and that safety must be sought principally in strength of pipe and fittings; but that the entire elimination of sleeves is not desirable as their presence in the line at reasonable intervals is convenient in its maintenance.

On the general subject of comparative physical conditions the following has been kindly contributed by Mr. E. R. Mason of the National Tube Company.

"Wrought Iron and Mild Steel Pipe.

"The relative merits of steel and iron pipe have created

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much discussion. The average physical properties of the two pipe materials may be taken as follows:

	Pipe steel	Wrought iron pulled Longitudinally
Tensile strength	58,000 lbs. per sq. in.	46,000 lbs. per sq. in.
Elastic limit	34,000 lbs. per sq. in.	28,000 lbs. per sq. in.
Elongation	22 per cent. in 8 ins.	12 per cent. in 8 ins.
Reduction in area....	55 per cent.	25 per cent.

"Wrought iron will vary from 4 to 16 per cent. in elongation, whereas steel may be expected to range from 19 to 25 per cent. Puddled iron pulled transversely seldom gives 35,000 pounds per square inch tensile strength, and thus elongation and reduction in area are proportionately low and variable.

"Comparing the chemical properties; wrought iron has a trace of carbon, while soft pipe steel has approximately 0.07 of 1 per cent.; wrought iron has 0.15 of 1 per cent. of manganese, while pipe steel has 0.30 of 1 per cent.; wrought iron has about 2 per cent. of oxides and slag, while pipe steel has less than 0.15 of 1 per cent., showing that steel which is made into pipe, and the pipe designated as 'steel pipe' is, in fact, a purer iron than so-called 'wrought iron pipe.' This can easily be proved by heating a piece of steel pipe to a bright red heat, chilling it suddenly in water and then crushing it, no hardening will be noticed. If it had the true characteristic properties of ordinary steel it would show same by being fractured.

"That the physical superiority of pipe steel is maintained in the finished tubes and pipe is indicated by actual bursting tests, made by Prof. R. T. Stewart, on many lengths of wrought iron and mild steel pipe. His conclusion from these tests is that, 'Butt-welded wrought iron pipe is 70 per cent. as strong as similar butt-welded steel pipe; and lap-welded wrought iron pipe is 57 per cent. as strong as similar lap-welded steel pipe.'*

"In so far as threading is concerned, when it is taken into consideration that pipe steel is softer but tougher than wrought iron, and threading dies designed accordingly, there is little

* Jour. A. S. M. E., April, 1912.

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difference in the power required to thread the two pipe materials. The advantage of threading all welded pipe with properly designed chasers is shown by Prof. T. N. Thomson's investigation, the conclusion of which follows:

" 'It shows that the power required to thread mild steel pipe with the new die is not much more than that required to thread wrought iron with the same die, and much less than the power required to thread wrought iron pipe with the common die.'*

"Improvements in manufacture have removed objections to the modern pipe material until the superiority of mild steel pipe in welding, bending and threading is pretty firmly established.

"*Corrosion.*—Thus it may safely be said at this time that the only important difference in opinion which exists regarding pipe is on the question of corrosion. For some time after steel pipe was first introduced there was, of course, lack of direct evidence from service tests on pipe so that conclusions were rather hastily formed by many from general observations on iron and steel of various kinds used for widely different purposes, or from hearsay, the foundation of which is more or less mythical.

"Steel pipe lines have now been in use for nearly 20 years so that by this time it is reasonable to expect comparative results from service. In order to interpret observations and form a correct conclusion regarding corrosion, it is important to have a clear conception of what is going on when iron rusts. The many factors which enter into the problem make it a complicated matter to arrive at comparisons or make predictions of the life of iron or steel, but the fundamental conditions are comparatively simple, involving the presence *together* of free oxygen and water.

"The chemical, or more strictly speaking, the electro-chemical reactions may be divided into two stages: first, solution of a small portion of iron; and secondly, oxidation of this iron to ferric hydroxide, commonly known as rust. The red oxide

* Proc. A. S. H and V. Engrs, 1906.

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thus formed is insoluble, therefore when precipitated leaves the way clear for more iron to enter solution and for the further combination of iron with oxygen. These reactions will continue so long as there is any oxygen, water or iron left. The absence of either water or free oxygen makes corrosion impossible. The rate of corrosion depends among other things on the amount of each of these elements present. The theory of corrosion might be greatly elaborated but would not be of much more practical use in explaining what we are all so familiar with in our every day work. The *rate* of solution and corrosion of iron is governed principally by the temperature and character of the water, galvanic action between dissimilar materials, electrolysis from stray currents and many other minor influences.

"It is surely evident then that there is nothing remarkable in the fact that pipe will sometimes last 20 years and show no serious damage, while in other places perhaps not far away, it will be perforated in a year or so. This has been the experience with wrought iron pipe before steel was thought of, and has been the experience with both materials since that time.

"In discussing this question before the American Society of Refrigerating Engineers in St. Louis, 1911, Mr. P. De C. Ball, who has had an experience of 33 years with pipe for refrigerating purposes, puts his conclusions in the following words:

" 'From 33 years of personal observation, constructing, erecting and operating ice-making and refrigerating machinery, absorption and compression types, and using iron pipes for the first 14 years and iron and steel pipe for the next 19 years, we are convinced that local conditions only govern the corrosion of pipes in refrigerating and ice-making machines, and that, chemically and mechanically, mild steel pipe meets the requirements of the refrigerating engineer in all respects, and better than other pipe, for the reason that it is superior in point of finish, strength, strength of seam and uniformity of material.'

"It has been found that the rate of corrosion is much more

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dependent on conditions external to the metal than on variations in the metal itself.

"In order, then, to form a correct conclusion on this question it is evidently of prime importance to know whether all the conditions surrounding the pipes were the same in every particular. Laboratory tests have been conducted under approximately natural conditions and were satisfactory so long as there was no better evidence from practical experience (acid tests are not referred to here, as they are usually very misleading).

"Based on several years of investigation in the laboratory and field, the National Tube Company, 6 years ago, decided to discontinue the manufacture of wrought iron pipe entirely. It may be of interest to outline the character of the investigations which led to this important departure in practice. Opinions and so-called experience unsupported by actual comparisons of the two materials under the same conditions were ignored as they were found to be inconsistent and misleading. Ever since steel pipe has been made, lap-welded wrought iron couplings have been used on account of the tendency of steel to gall, and perhaps because the tapping machinery was in earlier days better able to thread the wrought iron—so where local corrosion occurred in pipe lines there was always some of each material present. Further, as steel pipe came more generally into use it was apparently a common accident to make up both materials in the same line. The latter, under internal corrosion, affords the best possible comparison, and fortunately hundreds of such cases have been found without much difficulty. All these investigations have shown that practically no difference exists between wrought iron and steel pipe in general, in respect to corrosion.

"Figs. 1 and 2 are examples of the above, and indicate fairly the results, which were actually compared by measuring the depth of pitting below the original surface of the metal. The results of corrosion on wrought iron and steel pipes after several years' service compared in this way show no practical difference. Any one sufficiently interested can investigate pipe

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corrosion in this way—the character of the metal, *i. e.*, whether iron or steel, can be determined with a little practice by filing across the pipe which may be followed with etching or fracture tests when in doubt.

"Of interest to members of the American Gas Institute are ***underground*** tests, results of which are given in the *Proceed-*

Fig. 1.—Steel pipe with wrought iron couplings after 15 years service in Indiana oil fields.

ings, Vol. III, 1908, page 274, and Vol. VII, 1912, page 646. The conclusion of the former, that, 'the pitting on the steel pipe is probably more general all over the surface, but the pitting on the wrought iron pipe is deeper in the spots that are affected' is interesting in view of the fact that special mechanical working of the metal is done in National Tube

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Sample No. 57—Steel. Frick Coke Co. Investigation. Sample No. 59—Wrought Iron.

Sample No. 62—Wrought Iron. Allegheny Hospital Investigation. Sample No. 63—Steel.

Fig. 2.—Comparative corrosion of adjacent hot water pipes.

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Company's mills with the idea of securing uniform corrosion rather than pitting. The result of the latter test, that "We finally concluded that from the viewpoint of corrosion there was but little to choose between wrought iron and steel pipe" is interesting as indicating mild steel pipe to be as durable as wrought iron in underground work, just as this point has been substantiated under the many other conditions of service."

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"Corrosion and Preservation of Iron and Steel," by A. S. Cushman and H. A. Gardner.

"Metallurgy of Iron and Steel," by Bradley Stoughton.

The writer does not consider it within the scope of this paper to take decided ground upon the question of relative corrosion which has been disputed for years between the makers of the two kinds of pipe, who have brought to their assistance and support the tests and opinions of many learned experts.

In order that the presentation of the subject might be entirely unprejudiced, an expression from wrought iron interests was also invited and has been kindly contributed by Mr. Ernest A. Moore of A. M. Byers Company.

Further information can be found in a pamphlet issued by

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the Reading Iron Company entitled "Court of Actual Experience."

"Corrosion of Iron and Steel.

"A great amount of discussion has taken place and considerable investigation has been made in attempts to discover the reason for the greater resistance to corrosion which is shown by wrought iron than steel. The advocate of steel usually goes very fully into the fact of greater tensile strength and comes to a conclusion based on theoretical investigation, that there is very little difference, if any, in the lasting qualities of the two materials.

"It is not the intention to go into a theoretical discussion of this subject, but rather to point out some of the facts which may be recognized, and have been recognized by observant users of iron and steel, although frequently persons in no way specially interested nor having any knowledge of the materials other than in their uses. As a result of these observations the chemist and engineer are endeavoring to discover the theory explaining the fact that genuine wrought iron shows a very much greater resistance to corrosion than steel, but it is more the fact than the explanation in which the consumer is interested.

"The farmer was annoyed to find that his steel wire fences were rusting out in 5 or 6 years and less, while older fences of wrought iron were still in service after more than 20 years exposure. His complaints to the Government were so persistent and general that the Department of Agriculture was practically forced to investigate the matter, and some extracts from the writings of Mr. Allerton S. Cushman, Assistant Director, Office of Public Roads of the United States Department of Agriculture, will be found in the following pages.

"The 'old fashioned' wrought iron, which Mr. Cushman describes as made by the 'puddling method, which yielded most of the extremely durable wire that was found on the market many years ago' contained no steel scrap. In those days there was no steel scrap on the market, but of late years it has been

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so plentiful and cheap that it has been used in the manufacture of so-called wrought iron, and the unsatisfactory results obtained from this product have done much to further complicate the fair comparison of iron and steel, and have forced the trade to refer to 'genuine wrought iron, made by the hand puddling process, without the admixture of any scrap' when wrought iron is required. Iron and steel have different welding temperatures, and a mixture of the two brings about a lower grade product subject to laminations and flaws.

"The question of strength is usually brought up in connection with pipe, and may be dismissed very shortly. Wrought iron pipe is subjected to hydraulic pressures ranging from 750 to 2,000 pounds per square inch, which is so far in excess of the pressure usually found in service that the ultimate bursting strength is quite irrelevant. Regarding the strength of pipe in resisting stresses due to contraction and expansion and other stresses in service, while steel may show an additional tensile strength in laboratory test, this is more than offset by the physical qualities of wrought iron, which is less brittle, especially at low temperatures, and will adjust itself to conditions more readily than steel. The value of the pipe in maintaining its initial strength is far more important, and this brings us back to the resistance to corrosion where wrought iron has the advantage.

"It is the common experience of those who notice buildings composed of sheet steel, also roofs, wire, stove pipe and other articles in general use which were formerly made of wrought iron, that steel does not give anything like the service. These general facts are quite undeniable, but it is very difficult to condense the evidence to show a scientific proof satisfactory to the chemist and engineer. To illustrate this point we may cite the case of the chief chemist of one of the large electrical companies who wished to contract for a year's supply of wrought iron wire, explaining that steel wire in service 5 or 6 years was being replaced, while wrought iron wire in service over 20 years was in a fair condition. He had analyzed samples of the steel and iron wire, but had been unable to

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find any means in the laboratory which indicated this proved superiority of wrought iron, and was acting upon the results of actual service.

"Another phase of the matter is shown in the action of the steel manufacturer in producing what is known as 'Spellerized pipe' which has been claimed to be superior to ordinary steel pipe and 'equal' to wrought iron. The only reliable test of this pipe will be that of service, but on analysis we cannot find that it contains ingredients any different from those in ordinary steel pipe, and we do not expect that service will show any appreciable difference in life. The resistance to corrosion in wrought iron is largely due to the presence of silicon, and the elimination of manganese. It will be noticed that it is in these ingredients the greatest difference occurs between the iron and steel in the following analysis:

	Spellerized steel pipe	Merchants steel pipe	Genuine wrought iron pipe
Silicon	Trace	Trace	0.178
Manganese	0.27	0.20	None
Sulphur	0.032	0.046	0.029
Phosphorus	0.077	0.096	0.126
Carbon ..... (Combustion)	0.085	0.062	0.074

"On page 18 of *Farmers' Bulletin* No. 239, Mr. Cushman sets out the following conclusions:

'1. That modern Bessemer and open hearth steel rusts much more rapidly than iron wire.

'2. That manganese, especially if it is unevenly distributed in the steel, is at least in part the cause of the trouble.'

"Regarding electrolysis, in concluding *Bulletin* No. 30, Mr. Cushman says:

"'. . . It would follow from the electrolytic theory that in order to have the highest resistance to corrosion a metal should either be as free as possible from certain impurities, such as manganese, or should be so homogeneous as not to retain localized positive and negative nodes for a long time without

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change. Under the first condition the irons would seem to have the advantage, but under the second much would depend upon care exercised in manufacture, whatever process was used.'

"Assuming then equal care in manufacture wrought iron has the advantage, and further it may be said that in the puddling process where a charge weighs between 500 and 600 pounds and is hand worked under the eye of a competent puddler, there is much less chance of the charge receiving uneven heat treatment and coming out 'patchy,' than is the case with the open hearth process where one charge would be about twenty times as great. As a matter of fact the even grade of wrought iron is proved by superior cutting and threading qualities which are very well known. Large quantities of wrought iron pipe are sold for its ease of working for use where resistance to corrosion is of minor consideration, the extra cost of the wrought iron being justified by the saving in tools and labor.

"Another view of the matter may be gained by consideration of the relative price of wrought iron and steel. The cost of production of wrought iron is governed very largely by labor, and while improvements have been made in methods of manufacture, the cost has not been reduced in the same proportion as has been possible in the steel process, and we now find a difference of about 30 per cent. in the price of wrought iron and steel. In view of this difference, increasing recognition of wrought iron is in itself proof that after the test of long service, which is admittedly the only reliable one, genuine wrought iron has proved itself to be far superior to steel in its resistance to corrosion and in its machining qualities.

"Genuine wrought iron is made by the hand puddling process from straight pig iron without the admixture of any steel or so-called wrought iron scrap whatever, and has proved in actual service to be more than 300 per cent. longer lived than steel, showing that the slightly increased first cost is of no importance compared with the additional length of life in service."

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Coatings and Coverings.

On account of the well established fact that steel and wrought iron pipes are more susceptible to corrosive action than cast iron they are dependent for their maximum efficiency in underground service upon the use of a suitable protective coating or covering properly applied. Corrosion in underground pipe systems may be traced to either or both of two primary causes: the chemical action of the soil, and electrolytic action from stray currents; and the success of the protective agent will depend upon its ability to resist the particular conditions to which it is exposed. Much has been written on this subject during the past few years and many tests made. Reference may particularly be made to a comprehensive paper prepared by Mr. Robert B. Harper for the Illinois Gas Association meeting in 1909, entitled "Comparative Values of Various Coatings and Coverings for the Prevention of Soil and Electrolytic Corrosion of Iron Pipe." Mr. Harper goes into great detail and cites many valuable tests. No attempt will be made here to extract portions of Mr. Harper's observations and conclusions, the choice and limitation of which extracts would be difficult, but attention is invited to the whole of this admirable paper, careful study of which cannot fail to be of service to all who are interested in the subject. His conclusion in favor of clean coal tar pitch, free from water, acids or soluble mineral matter and his limitation of the value of cloth or paper coverings are especially interesting.

Pipe for use within a limited distribution area is usually coated at a central point where heat is available. When the dipping method is used the bath should be hot, and the pipe should remain in it until it has acquired the temperature of the bath. When the painting method is used, both the pipe and the paint should be hot. Before coating, the pipe surface must be rubbed or brushed clean of mill scale and rust. Carelessness in this respect is responsible for many quick failures of coatings. If rust is heavy, a coat of rust removing oil should be applied before cleaning. The coated pipe must be

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carefully piled with each length isolated by the use of vertical and horizontal separating strips. The after handling and transportation demands most careful oversight and the training of all members of the force to the recognition of the fact that damaged coating is no coating at all but only a waste of money. It is in this respect that the additional protection of cloth or paper wrapping becomes of particular value, and when soils are unusually bad or electric currents to be feared, this extra protection should be used. In such cases the under coating may be given the additional efficiency of extra thickness and hardness without fear of the effect of brittleness, the wrapper receiving a thinner and more flexible coating. For unusually severe electrolytic conditions heavily pitching the pipe in a V-shaped trough is of especial value.

In pipe line work where the pipe is received at many outlying points and transportation is difficult at best, coating on the job is generally to be preferred. In such cases, a portable or traction boiler is a valuable addition to the equipment.

Whatever the method of the initial coating, or the care with which it is done, some re-coating is always necessary after the pipe is laid, and this must necessarily be done on the cold pipe. The coating for this work must therefore be kept at full heat and the best of care given the work, the need for which should be minimized in the handling of the pipe and tools to the greatest degree possible.

Main Laying.

In taking up now the details of the actual laying of wrought iron and steel mains reference may be made to the paper of Mr. Walton Forstall before this meeting. It will not be necessary to here repeat the general details and data therein so carefully compiled and common to all pipe laying, but attention will be directed to certain differences in organization, equipment, and other details caused solely by the use of a different character of material.

Organization—City Work.

In all city or small town work the question of organization

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is of much less importance than in cast iron work. Any competent service man or fitter, with sufficient executive ability to direct the larger gang of men, and a little preliminary training in the handling of dirt and pavement, can be entrusted with the laying of screw joint mains, subject to the usual oversight of a local manager, superintendent or general foreman. The main gang is often in fact, especially in the smaller towns, only a service gang temporarily enlarged, and needs no separate special organization.

Pipe Lines.

The organization for laying a long country pipe line is of more special and particular character. It is generally of sufficient importance in any organization to warrant a special work order, and the direct supervision of the engineering department. Special and careful arrangements are necessary—

1. For the unloading, handling and placing of the long mileage of pipe required.

2. For the coating of the same.

In city work, pipe is ordinarily and most economically coated at some central point and the coated pipe carefully distributed. In pipe line work there is not an established plant for coating at each unloading point, and the delivery over long stretches of road, frequently rough, cannot always be controlled in such measure that the coated pipe may be properly protected. It will be found far better in pipe line work to coat the pipe after the same has been distributed, and for this purpose a traction or other portable form of boiler is very desirable. Such a boiler is moved along the line, heating each length of pipe through a rubber hose, the painting gang follows closely, and the pipe carefully placed on blocks, is ultimately given two good coats, and is ready for laying as soon as the coating is dry.

3. For necessary housing and commissary arrangements, transportation of men and material and communication.

4. For the actual organization.

A general foreman should be placed in charge of the

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entire pipe line job, and great care should be used in choosing this man. It must be realized that the work is frequently isolated, and that decisions must often be quickly made without reference to the supervising officials. This foreman should be a man experienced in dealing with high pressure gas; a man of tact, and able to deal with questions that may come up suddenly along the right of way, and he should be a good executive, especially able to handle the many foreign races of men who are employed on this class of work. He should be provided with some means of reasonably quick transportation. This should preferably be a wagon or motor capable of making emergency delivery of material from the nearest freight station.

The men on the work should be divided into plowers, diggers, pipe layers, recoating and testing men and ditch fillers.

The plowing gang will consist of a foreman on the plow, and a driver for each team of horses, from 4 to 8 horses being used according to the character of the soil. It is desirable, as far as possible, in hiring teams for pipe line work, to obtain them from the farmers along the road, thus promoting good feeling. The first furrow is turned with a breaking plow, and this is followed with a special rooter made with contracted handles to enable deep plowing. The plowing should turn the earth to a depth of 2 feet 6 inches, and the furrow should be made as straight and true as possible.

The size of the digging gang will be determined by the nature of the soil and the speed of the pipe gang. These men should have a foreman of their own nationality, and as far as possible only one race should be employed. The foreman is generally a padrone and the general foreman in charge should attend to his development for the particular necessities of the work.

Each pipe gang, and there may be one or more of these according to the speed desired, the work being divided up into sections, should be in charge of an experienced pipe man, and he should be allowed to recruit his gang from the

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most intelligent of the laborers. Generally some men of experience are found in these laboring gangs who are capable of acting as helpers. If not, a man must be sent from the fitting shop, as there should be at least one good man in each gang capable of assisting the foreman in the handling, entering and screwing of the pipe. For 4 inch pipe, a total of 5 men, in addition to the foreman, is desirable in each pipe gang. Eight inch pipe will require 12 men and other sizes in proportion. The pipe gang attends to the reversing of couplings, doping joints, and to swabbing out which is always carefully done with each piece of pipe before laying. This gang also puts on all sleeves, valves and other special fittings.

The testing gang may consist of one or more men according to the speed required, and any intelligent English speaking laborers may be employed, working under the supervision of the general foreman. These men turn the pressure on, make the soap-suds test, and mark and report all leaks to the general foreman, who should directly supervise the placing of the leak clamps or the tightening of the joint if that be possible.

For filling, a winged plow is used, followed by a road grader, with necessary men and horses to each, according to the character of the earth.

Digging Machines.

With the gradual perfecting of gasoline driven digging machines, the possibilities of these machines for long stretches of uninterrupted work are becoming more interesting to distribution engineers. These possibilities are especially evident in connection with cross country pipe lines, and particularly so, it may be observed, in relation to the growing scarcity of common labor, which is being appreciably felt at the present time. Where digging machines can be employed, the plowing and digging gangs become unnecessary, the pipe gang is slightly enlarged and is used to take care of the small amount of digging required over crossings or any spots necessarily skipped by the machine. The camp to be maintained is much

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smaller, equipment much more limited, and the whole organization becomes more simple, which is a matter of no small consideration in isolated country work.

The purchase of a trenching machine of course presupposes enough work contemplated to warrant the expenditure.

In this class of work there are certain requirements which a machine must fill before it can be considered at all. First, it must be comparatively light on account of possible rough roads, and the fact that pipe lines are ordinarily laid between the wagon road and the fence line. On a country road this implies gullies, ditches, streams of water, swampy places and rough going generally, which necessitates considerable blocking. Second, it must be of narrow beam so that it will not block the whole road, and so that it can be worked between the roadway and the fence when the road is highly piked. Third, it must operate on a convenient form of fuel, as a large part of pipe line work is in isolated spots. Fourth, it must be well constructed. Frequent delays on account of breakage will hold up the pipe laying gang, and soon increase the cost to a figure higher than hand trenching. Fifth, it must be able to maintain a fairly high rate of speed when working under favorable conditions. This is necessary in order that the average ditch dug under all conditions will be sufficient to keep ahead of the pipe gang. Sixth, it should throw the dirt toward but one side of the ditch, toward the road, leaving the other side free for working. It should be interchangeable in order that it can run on either side of the road, and it should throw the dirt close to the edge of the ditch so that back filling will be easy. Seventh, it must trench cheaply. The cost per foot must show enough saving to pay for the interest and depreciation.

A brief description of a machine thought to fill these requirements and now in use on pipe line work under the writer's supervision may be of interest. This machine was purchased this spring at a cost of $5,000 and immediately put to work to dig a continuous stretch of 30 miles. It is of the endless chain bucket type and is driven by a 25 horse-power 4 cylinder

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gasoline engine, water cooled. Its dimensions are—length 36 feet from end to end when the boom is out of the ground for road travel or on car; width over all 8 feet, height 12 feet, wheel base 13 feet. Its weight is 27,000 pounds. It cuts a trench 18 inches, 22 inches, 24 inches or 28 inches wide and any depth up to 10 feet, at a graduated speed of from 1 to 5 feet per minute, depending upon the width and depth required and the nature of the soil. The dirt is thrown by a conveyor to either side of the road, and by using the deflector provided, can be thrown within one foot of the edge of the ditch.

The traction wheels consist of a multipedal apron on each side of the machine. This permits its being run through very soft ground without becoming mired. It is strongly and simply constructed throughout, the parts receiving the heaviest wear being constructed of manganese steel. It has a road speed of 2 to 3 miles per hour when running from one job to another, and it can be easily loaded on a flat car under its own power when desired for transportation to distant points.

The possibilities of this machine may be seen by the daily reports of work done from May 10 to May 24, 1913. The reports show:

Date	Distance	Total cost	Cost per foot
May 10	1,450 feet	$11.38	0.0078
May 11	926 feet	11.80	0.0127
May 12	1,430 feet	13.38	0.0093
May 13	560 feet	8.02	0.0143
May 14	rain		
May 15	1,020 feet	9.65	0.0094
May 16	1,200 feet	11.50	0.0096
May 17	1,250 feet	11.25	0.009
May 18	630 feet	9.49	0.0151
May 19	1,300 feet	13.35	0.0103
May 20	rain		
May 21	rain		
May 22	rain		
May 23	785 feet	9.03	0.0115
May 24	1,257 feet	11.51	0.0091

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A total distance of 11,808 feet in 11 actual working days, at a total cost of $120.36, or 1,073 feet per day at 1.02 cents per foot. This cost includes the operator and assistant, board bill of the operator, some teaming, gasoline, lubricants and a few minor repairs. It does not include the wages and board of the operator during the rainy days which bring the cost up to 1.15 cents per foot. This digging was done through a very wet sticky clay, some gravel with a few rocks, roots of trees, etc. The ditch was 24 inches wide and 4 feet deep. Ground conditions were favorable to the extent that little blocking was required.

The advantages of machines of this character, namely, low cost per foot, simplified organization, and freedom to a large extent from labor troubles, are so manifest that their increased use on work of this description seems assured.

EQUIPMENT.

For laying 2, 3 and 4 inch low pressure screw joint mains in a town or city, the necessary equipment is as follows:

4 3 inch bags
4 4 inch bags
3 Tamping bars
2 Tunneling bars
2 Rock drills
1 Steel brush
1 Bucket (galvanized iron) and 2 cups
1 Fitter's tool cart
1 Laborer's tool cart
1 No. 2 pipe cutter
1 No. 4 pipe cutter
1 Chisel bar
1 Cold chisel
Fittings and nipples, assortment
2 14 inch bastard files
1 Machinist's hammer
2 Striking hammers, 10 pounds
1 18 pound sledge
200 feet of hose with hydrant connection

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8 Red kerosene lanterns
1 18 inch level
1 Line (ditch), 250 feet
1 Tape line, 50 feet
1 Oil can
2 Gallons pipe paint and brushes
Pipe dope and brush
10 Picks (3 extra handles)
25 feet ¾ inch rope
10 Shovels
10 Spades
Soap, test can and brush
1 Tapping machine, dies ¾ inch to 2 inches
1 Pair chain tongs
1 Wrench or lay tong, 3 inches and 4 inches.
1 36 inch Stillson wrench
1 24 inch Stillson wrench
2 18 inch Stillson wrenches
1 12 inch monkey wrench
10 Yards wrapping (muslin)

For high pressure street main work, the equipment is approximately the same. Gas bags are not needed. The extra fittings should be all high pressure type, and include valves, extra sleeve rubbers, saddles, etc. Tapping machines and taps must be all high pressure type. Also add valve keys and tee saddle shut-off plugs.

The following equipment is necessary for laying a 3 inch or 4 inch high pressure pipe line. Changes for other sizes are self-evident:

4 Tunneling bars
2 Rock drills
3 Steel brushes
2 Galvanized iron buckets and 2 cups
1 Fitter's tool cart
1 Laborer's tool cart
1 Pair pipe cutters (3 wheel), 6 extra wheels
1 Chisel bar

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1 Cold chisel
Fittings and nipples, assortment, shop tested
6 14 inch flat bastard files
1 Machinist's hammer
2 10 pound striking hammers
1 18 pound sledge
18 Red kerosene lanterns
1 Dozen extra lantern burners
1 Dozen wicks
1 Dozen globes
1 18 inch level
1 Trench line, 500 feet
1 Tape line, 100 feet
2 Oil cans
5 Gallons pipe paint and brushes
50 Pounds pipe dope and brushes
Picks (1 for each laborer plus 6 extra), also
1 dozen extra handles
6 3 inch wooden plugs
6 4 inch wooden plugs
1 Breaking plow
1 Rooter plow
1 Wing plow
1 Road grader
75 Feet of rope, ¾ inch
Shovels (1 for each laborer and 6 extra)
Spades (1 for each laborer and 6 extra)
Soap, 3 test cans and brushes
2 Wrenches or lay tongs, 3 inches and 4 inches
1 Pair chain tongs
1 Tapping machine, ⅜ inch to ¾ inch
1 36 inch Stillson wrench
1 24 inch Stillson wrench
1 18 inch Stillson wrench
2 14 inch Monkey wrenches
1 Valve key
Portable or traction boiler for pipe coating

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For cast iron work Mr. Forstall gives 18 inches as a satisfactory width of trench for all sizes of pipe up to and including 8 inch. The trench for screw joint pipe is made of uniform width throughout. This width must be sufficient for the proper handling of the pipe in the ditch, where it is screwed up in the ditch, including the recoating of the same, and should preferably be 18 inches for pipe up to and including 3 inches in size, 20 inches for 4 inch pipe, 22 inches for 6 inch pipe, and 24 inches for 8 inch pipe. Where pipe is screwed up on top and afterwards lowered in the ditch, especially in the case of the smaller sizes for high pressure town work, a ditch as narrow as 12 inches may be found satisfactory.

The usual practice in low pressure city work, 2, 3 and 4 inch pipe, is to joint all pipe in the ditch and block carefully as in cast iron work. On account of the strength of the pipe stone blocking can be used provided this is cheaper or more convenient. The grading must be carefully done and the grade increased slightly with the smaller sizes. All pipe, whether for low or high pressure work, should be ordered with loose couplings, and the couplings should in all cases be removed and the threads redoped. Each length of pipe should be carefully cleaned, the thread entered with great care and the pipe screwed up until the joint practically refuses to turn farther. Judgment as to the exact strain or "feel of the joint" can only be gained by experience. It must be borne in mind that the secret of tight joints lies mainly in full union of thread and coupling, and that careful work should practically never show a leak under ordinary gas pressure. Low pressure work of this character is generally tested under the ordinary gas pressure using soap suds, practically the same test as is given service piping. The general experience is that leaks are exceedingly few in low pressure construction, and can usually be corrected by pulling up the pipe. Inquiry made of one system of considerable size brought the statement that for several years they had not found it necessary

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to use a single leak clamp in correcting leakage in their low pressure construction.

For retouching tool marks and at joints, the smaller sizes of pipe may be lifted by hand, while in the larger sizes the dirt must be removed to allow the under side of the pipe to be reached.

In high pressure work the question of exact grade is not of the same importance as in low pressure construction. The moisture can be forced along the pipe, and it can usually be entirely removed in the first mile of pipe line, after which grading becomes of little importance. It is customary to grade pipe lines to the extent of avoiding an unnecessary number of pockets or low places, but this does not mean a careful grade such as is necessary in low pressure work; blocking is not used, and the pipe is best allowed to rest upon the solid ground of the trench as excavated. Low places are recorded, but it is not customary to install drips after the first mile or two.

Opinions and practices differ regarding the relative advantages of jointing high pressure pipe line in the ditch or upon the bank. Both practices have their strong adherents, advocating the greater efficiency of their particular method. In wet country the advantage is unquestionably with the outside method, and pipe may be successfully jointed and lowered into ditches filled with water, the water in fact acting as an excellent testing medium. Where pipe is jointed on the bank, it is usually retouched before being lowered into the ditch, but the final test must invariably be made after it is finally bedded. In small pipe work such as is found in town high pressure distributing systems, sizes from 1 inch to 2 inch, with the bulk of the system probably 1¼ inches and 1½ inches, the practice is quite generally followed of stringing the pipe on wooden supports over the center of the trench, retouching and lowering at short intervals. Work of this character is seldom laid to careful grade, and no blocking is used, as the

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presence of moisture is not feared in these areas. Trenches in these cases may be cut very narrow.

High pressure piping is preferably tested with gas at a pressure exceeding the maximum which the line will be called upon to stand. Where town piping is operated at a reduced pressure controlled by a governor, it is frequently possible to obtain this condition, by-passing the governor, and testing the new mains with the full pipe line pressure. In the case of pipe lines it is not always practicable to obtain even the maximum gas pressure at all times for testing; in such cases air pressure may be resorted to, but this is less reliable and many engineers prefer to test their pipe lines with gas at a lower pressure than with air at the desired pressure. Pipe lines testing bottle tight at 25 pounds pressure will be almost invariably found tight at 50 pounds, and while testing at half pressure is not desirable, if it can be avoided, it may be reasonably depended upon when necessary. All testing should be done with soap suds and by careful men, carefully supervised. Pipe lines are generally tested in sections of one-half mile or more between valve stations, and the testing must invariably be done after the pipe is on its bed. The position and character of the leaks will determine whether or not an attempt can be made to take them up in the joint. If the first work has been carefully done, it is seldom found that after leakage can be corrected in the joint and the cause in such cases will be found in the fit of the joint itself. Such leakage can only be corrected by the use of leak clamps, and these clamps, carefully applied, are found secure and reliable. With well made pipe and good work on the job, the number of leak clamps necessary should not average in pipe line work over 10 to the mile.

In screwing up all pipe, great care should be taken to injure the coating as little as possible. In the smaller sizes much of the first turning can be done by hand. In the large sizes the preliminary screwing up can be best done with a rope twist, which is both quick and efficient. Wrenches and tongs

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should be applied close to the couplings and moved as little as possible.

At all points where pipe lines or other long stretches of screw joint pipe change direction, not in the neighborhood of a flexible joint, the trench should be widened out at least 1 foot the entire length of the bend. The study of a large number of pipe line breaks has developed the fact that the breakage is especially severe during the first year when the pipe is seeking its final bed, and that a large proportion of such adjustment breaks, if they may be so termed, occur where there is a change of direction in hard soil.

Fittings.

The choice of fittings in low pressure work lies between malleable, cast iron, and fittings of the Dresser type, hereafter referred to for convenience as slip fittings. For high pressure work the choice is between extra heavy cast iron, slip fittings, and, in the smaller sizes, galvanized malleable. The principal objection to ordinary malleable fittings is found in the threads. Experience shows that cast iron fittings are more trustworthy in this respect, and that pipe laid with these fittings develops less after leakage than when laid with malleable. Cast iron fittings used on high pressure work should always be extra heavy, as the additional strength is of advantage, and the fittings themselves are more likely to test tight. All fittings installed in high pressure work, except slip fittings which can be easily removed, should be tested as to tightness in the body of the fitting itself before being installed in the line. Careful work in this respect will save much after expense. Galvanized malleable fittings may be safely used in the smaller sizes of high pressure work, 1½ inch and smaller. Ordinary malleable fittings should never be used in high pressure work because, in addition to the objection above cited, there is the additional objection of porosity. Slip joint fittings have the advantage of easy installation; they are generally well made, without any objection as to porosity, and they provide for expansion and contraction. The disadvantages may be found

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in the life of the gaskets, and in the difficulty of renewal of these gaskets in all slip joint fittings other than sleeves. The renewal of a gasket in the case of a sleeve is easily made by sliding the sleeve upon the pipe. In the case of a slip joint tee or cross, the fitting cannot be slid back and forth, and the renewal of a whole gasket cannot be accomplished. This objection has been somewhat overcome in the case of rubber gaskets by the use of a split rubber, with the joint cut on an angle, and these split rubbers have proved quite successful in practice when carefully cut and applied. The life of rubber gaskets as used in these slip joint fittings is a subject which deserves more careful study than it has received. In many cases these gaskets are found to suffer practically no deterioration at all as time goes on. The writer recently examined a rubber gasket which had been underground for 7 years, and was in its original condition, absolutely perfect as far as could be observed. The sleeve in which this was used was lying in dry soil, well drained, at a depth of about 3 feet. On the other hand, these gaskets have been known to deteriorate very rapidly. This can frequently be traced to abrasion due to constant movement of the pipe within the joint, as in the case of slip joint fittings used in proximity to exposed lines, such as bridge lines. In these cases the gaskets wear rapidly, and slip joint fittings used to take up expansion of this character need frequent and careful attention. Aside from this, there is occasionally failure of the rubber itself, doubtless due in many cases to the chemical action of the soil upon the rubber; also where the gas transmitted contains any considerable portion of condensible hydrocarbons, deterioration of gaskets will be accelerated. One manufacturer of slip joint fittings has recently placed upon the market two special types of rubber gaskets, one tipped with duck and the other with lead. These are especially designed to resist the effect of abrasion, and gaskets of each type are now under observation, but sufficient time has not elapsed to express an opinion.

Another manufacturer has lately placed upon the market

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an asbestos gasket which is claimed to remain tight and unimpaired under all conditions. Mr. W. I. Battin kindly gives the following account of his experience with these gaskets:

"We really have had very little experience with asbestos gaskets, although we started a year ago using nothing but asbestos gaskets, both for artificial gas and for natural gas. We did this after getting what little information was available throughout the country, but more particularly because we had found that in our own experience through the past years, where we had trouble with the rubber gaskets being eaten out because of deposit of hydro-carbon from the gas we were able to overcome this trouble by putting asbestos in ahead of rubber gaskets.

"Our workmen in the other towns had also used asbestos a great deal in previous years where they had been shy on rubber gaskets, and the examination of the old sleeves which had been taken out for various reasons showed that they had held tight.

"Now in the new work which we did last year, we used perhaps 500 8-inch gaskets on artificial gas and probably 4,000 1¼-inch gaskets and a few of other sizes, and while our men seem to think that they make up just as tight at the start as the rubber gaskets, of course the length of time has not been sufficient to be of any value in stating their worth in actual practice, but no leaks have developed as far as I can find where the asbestos gaskets have been used. I do not know whether the asbestos gaskets will stand any better than the rubber gaskets where there is a movement of the pipe. Of course we know that the rubber gasket stands well when new and not dissolved by hydro-carbon, but it is only a question of time when rubber gaskets get hard and the flexibility of the joint is entirely lost, so that if there is a movement, the gasket simply breaks under these conditions, in the case of rubber."

Conditions in the Indiana Lighting Company's system were, it will be noted, much aggravated by the chemical action of the gas condensate. Their further experience will be watched

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with great interest, and in fact this is a field of investigation which invites the attention of all engineers using this type of fitting. On the other hand it must not be understood that the general experience with rubber gaskets has been unfavorable. Thus the lack of experiment as to different types has been largely due to the fact that renewals even in the oldest systems have been surprisingly few.

An interesting comment on this is the suggestion that this is possibly a proof that pipe lines find a permanent bed and thereafter do not move at all, the argument being that there must exist in these older systems large numbers of rubber gaskets sufficiently deteriorated that the slightest motion of the pipe will disintegrate their surface and start leakage. Under this theory the pipe presumably resists by its tensile strength the strain of contraction. The packed or frozen earth anchors it at intervals, and the condition is much the same as in the case of the continuous rail of street railroad systems fastened to the ties and resisting even greater changes of temperature.

A minor disadvantage in the use of slip joint tees and crosses is found in the slip feature itself, in cases where it is desirable to leave an opening for future use. Thus where an extra opening is provided, and a short piece of pipe run out and capped, it is necessary to provide, in high pressure work, special anchorage for the piece of pipe thus dead ended, otherwise the pressure may force it out of the joint. Slip joint elbows must also be carefully anchored or both joints may be forced out.

Cast iron fittings used in high pressure pipe lines should invariably be protected on each side by slip joint sleeves. Valves should receive the same protection. The strains on long pipe lines have already been noted and require this safeguard. Strains in city or town work, both high and low pressure, are more broken up and consequently less severe. Where slip joint tees and crosses are used, no other slip joint fittings are necessary, except to protect valves. Where cast

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iron tees and crosses are used it is customary to use one or two sleeves in each block according to its length.

In high pressure town work galvanized malleable fittings may be safely used in all sizes under 2 inch; little trouble is experienced from threads in these smaller sized fittings, and they are generally found satisfactory as to strength and tightness.

For closing in gaps or cutting in fittings, either in new work or repairs, slip joint sleeves are of great convenience in both high and low pressure work. The only possible objection to their use is that already discussed in the life of the gaskets. This becomes of special importance in work done under pavement. The only alternatives are cast iron sleeves with lead or cement joints, and, in the smaller sizes 2 inches and under, connections of the union type; long sleeves, ground joint or lead gasket unions, etc. Of these union fittings the so-called grip pipe couplings are worthy of consideration, giving a tight and sturdy joint without great difficulty of installation. While it is doubtless desirable to minimize the number of slip joint fittings under pavement, the writer feels that the experience with these fittings has been too generally favorable to warrant any serious apprehension as to their use under pavement when otherwise desirable.

The following will be found good practice.

Low pressure city and town systems: Fittings at intersections, cast iron screw fittings, ordinary weight. One slip joint sleeve for each block 400 feet and under; 2 sleeves for longer blocks; locations carefully marked.

High pressure town work: Extra heavy cast iron or slip joint fittings at intersections. Galvanized malleable may be used for sizes under 2 inch. All valves must have one slip joint in close proximity. Thus where slip joint fittings are not used a sleeve must be inserted near each valve.

Pipe line work: For elbows, the pipe to be bent wherever possible. When necessary to use a fitting, only extra heavy cast iron to be used. Slip joint ells not desirable in that they require outside braces. For tees and crosses, slip joint fittings preferable, except where one or more openings are dead ended,

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in which case extra heavy cast iron may be used to advantage. All extra heavy cast iron fittings and all valves must be protected by slip joint sleeves on each side. Other slip joint sleeves should be installed in the line at intervals, but should not be depended upon to relieve the line of strain unless installed as close as 200 feet apart.

Valves and Valve Systems.

Treatment of this portion of the subject will be confined to high pressure work as the use of valves in low pressure work is a matter of individual preference and there is no essential difference between screw joint pipe systems and those of cast iron in this respect.

Valves should be inserted in pipe lines in order that any portion of the line may be closed off quickly in case of a break or for repairs. The general practice has been to place these valves at half mile intervals. All iron valves of a good make, substantially built, and strong in the body, should be used for this work. The efficiency of the valves in pipe lines is often seriously impaired by the presence of foreign matter under the seat of the valve. Mill scale may, in spite of care, remain on the interior of the pipe, become dislodged later and find the pocket of some valve as its first resting place. Great trouble has been experienced in many lines from the presence in considerable quantity of a fine black powder flowing freely along the line and lodging in all available spaces, preventing pipe line valves from closing and occasionally entering the small distributing systems, the only remedy being to blow it out under pressure. One set of analyses of this material showed that it was 60 per cent. insoluble, and the insoluble portion contained about 94 per cent. of iron oxide, the remainder being mostly carbon, while the volatile matter appeared to be made up of coal tar pitch or some substance of similar nature. This powder may result from several causes, or a combination of all; oxide dust carried over from the purifying boxes, rust from the interior of the pipe, lubricating oils from the gas cylinders of the compressors, hydro-carbons from the gas itself. Whatever be the

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exact combination of substances and pressure which produces this dust in any given pipe line system, its presence is a constant menace to the valves, and it is frequently necessary where this trouble exists, to shut several valves and occasionally vent at sleeves between valves before it is safe to work upon the line. Pipe line valves should in all cases be specified with a plugged hole at the bottom for cleaning the pocket under the gates, and where so provided, any accumulated dust or scale may often be completely blown out when found to be present, and the valve again made tight if the seats have not been injured. In view of the difficulty of maintaining a completely tight system of valves, one large high pressure system has recently changed from single valve stations located a half mile apart to double valve stations located one mile apart. These double valve stations consist of 2 valves about 10 feet apart with a vent between. This company has of late years found it almost invariably necessary to close 2 or more valves on each side of any repair job and vent between by opening a sleeve, and it is thought that the new system will simplify matters. All valves used by this company are provided with blow-out holes for cleaning.

There should be a sufficient number of boxes in any pipe line system to give complete control of the gas supply in case of any sudden break, and this is especially necessary in northern climates where the ground freezes hard in winter. It is not always necessary to box all the valves in a system, and as it is difficult to maintain these stations free from dirt or ice, they should be selected with particular care, and afterwards carefully maintained, especially during periods when the ground is frozen.

In high pressure distributing systems valves should be placed at intersections where new lines branch off, and should be sufficiently frequent in the system so that construction and repair work may be undertaken without shutting off many customers at once. Gate valves should be used for all sizes down to and including 1½ inch pipe, that is, feeding mains. Globe valves may be used on the smaller sizes if preferred, as there

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is always a surplus of capacity in these lines which in high pressure work are always necessarily larger than actually required for the local distribution area to be fed. Globe valves are preferred by some builders because of their greater freedom from dust deposits. Gate valves should have cleaning holes at the bottom the same as in the case of pipe line valves. Plug cocks may be used for 1 inch mains, but in the larger sizes trouble may be experienced unless a very expensive design of cock is used.

The design of a city or town high pressure valve system for the quick isolation of any sudden break must be carefully studied. The boxing of every valve in such a system means expensive inspection and maintenance if the boxes are to be kept constantly in efficient condition. To be depended upon for the quick stoppage of any sudden leakage, valve stations must be found and used without a moment's lost time. In seasons of snow they must be kept cleared, covers must be free from ice, and the interior of the boxes known at all times to be free from dirt or ice. It is better to have a few valves in boxes properly maintained than a large number of doubtful security. Dead ends are of no apparent disadvantage in high pressure main systems, and it is therefore possible to divide any given distribution system up into areas of reasonable size controlled by a master valve. It is the practice of one large company to divide all of its town high pressure distribution system into such areas, carefully marked upon the town maps, one valve station controlling each area. These valves are the only valves boxed, and these stations are carefully maintained at all seasons of the year, especially in the winter. All foremen are drilled as to locating these stations; the distribution maps are arranged so that a moment's glance will show the controlling station of any particular locality; valve keys are carefully distributed. For the past 3 years this arrangement has been found to answer all requirements. The valves local to each street are dug up and closed by hand when construction or repair work is being done upon that street in the open season. The towns of this company are operated at 10 pounds pres-

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sure, controlled by reducing governors. No curb cocks or boxes are used on services within such distribution areas, the desire being to minimize the number of controlling stations and concentrate attention upon the stations in use. At 10 pounds pressure no valves have as yet been found to seriously fail. The total gas capacity of any area 4 or 5 blocks square is very small in these small pipe systems when operated at 10 pounds pressure. Services on the main pipe line outside the distribution area are provided with valves and boxes. The boxes in these cases are of sufficient diameter so that no valve key is required, and valves are used in place of cocks.

The design of all high pressure systems should be such that high pressure gas can be quickly and surely shut off at need; in all such cases valves are more dependable than cocks, which frequently become corroded after they have been in the ground for a time, and fail of operation with the key.

Depth of Mains.

This subject is referred to only to call attention to the fact, now better understood than formerly, that high pressure mains must receive the same protection from extreme cold as low pressure mains. Gas of a given quality will always suffer a certain deterioration in compressing and afterwards cooling to ground temperature, and this deterioration will be greater than would be the case if the gas were not compressed. Because of this, however, it does not follow that further deterioration will not ensue when the gas is further cooled. The amount of hydro-carbon vapors the gas will retain will decrease either as the pressure increases at constant temperature, or the temperature decreases at constant pressure. High pressure lines should therefore receive the same covering as low pressure lines, and all exposed places, such as bridge crossings, should be carefully protected.

Service Tapping.

For 1 inch or 1¼ inch services, a 2 inch low pressure steel or wrought iron main should be drilled with a ½ inch hole, and a plain saddle should be applied, tapped ¾ inch. For

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larger services from a 2 inch main, the main should be cut and full sized tee inserted. For 1 inch, 1¼ inch and 1½ inch services from a 3 inch low pressure main, a ¾ inch hole should be drilled and a 3 inch plain saddle used, tapped ¾ inch or 1 inch. For 2 inch services or larger, the main should be cut and a full sized tee inserted. For 1 inch and 1¼ inch services from 4 inch low pressure main, a ¾ inch hole should be tapped. No saddle is required. For 1½ inch services a 1 inch hole may be drilled, in which case a plain saddle tapped 1 inch should be used. For services 2 inches or larger, the main should be cut and a full sized tee inserted. For inserting bags in 3 inch and 4 inch mains, ¾ inch holes should be tapped for 3 inch bags and 1 inch holes for 4 inch. All high pressure mains larger than 1 inch should be drilled with a ⅜ inch hole, over which a tee saddle should be carefully applied. For service connections from 1 inch high pressure mains, galvanized tees should be used.

While not best high pressure practice small mains may be safely connected to larger mains by using drilled hole and saddles. One inch mains may be taken out of 3 inch or larger, tapping ¾ inch hole and other sizes in proportion. The connection should be on the side of the large main and a slip joint sleeve installed in the small main close to the connection.

Removal of Moisture—High Pressure.

All moisture should be removed from high pressure gas as soon as possible after the gas reaches ground temperature. This is most conveniently done by employing a baffle plate or series of plates on the principle of a steam separator. If the line itself is used as the condenser, the locations for the baffle plate tees or baffle plate tanks should be at low points in the first 2 miles of the pipe line. The base of some steep hill is an especially favorable point. If the high pressure gas is cooled at the pumping station, baffle tanks at that point may be depended upon to remove the greater part of the moisture. The pipe line up to the last baffle should be laid below frost line if this can possibly be done. There is great danger of

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ice formation where high pressure gas is exposed to low temperatures before removal of the greater part of its moisture, and this danger is especially great on up grades where the moisture flows slowly back against the flow of the gas. Bridge lines located close to pumping stations must be watched with especial care. Under certain conditions such exposed lines may be left partly or wholly uncovered and used as condensers, but the rate of gas flow and length of pipe exposed, with resulting temperatures along the exposed line, must be carefully watched to prevent the formation of films of ice on the interior of the pipe. When such films form during periods of extreme cold weather, and a warmer period sets in, the films fall off and form slush in the pipe which carried along in the pipe may jam at some point difficult of access and completely stop the flow of the gas. The safest method of using the pipe line as a condenser is that already suggested of bringing the gas gradually to ground temperature below frost level and then removing the moisture. There is little danger beyond this point in any pipe line, even where the pipe is later exposed to lower temperatures, for the reason that as the pressure falls along the line, the moisture capacity of the gas is increased, and its moisture capacity at a lower temperature may be practically the same at the lower pressure as at the original pressure and temperature. It is of course possible to produce an additional deposit of water in any high pressure system by extreme exposure. Thus one case may be cited of a high pressure service located 25 miles from the pumping station, becoming closed with frost, but this was a case of extreme exposure in an areaway with a temperature below zero. This service was at pipe line pressure. It is doubtful if this could have happened under reduced governor pressure. The general experience is that practically no moisture or frost trouble is found in high pressure systems after the moisture is once carefully removed at initial pressure and ground temperature.

Reducing Governors.

Where two or more towns are supplied from one pipe line, it will be found best practice to place a reducing governor at

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the entrance to each town, thus making the pressure on the town distributing system independent of the pipe line pressure. Pipe line pressures may necessarily vary widely between periods of peak load and light load, while at the same time the town distributing system need not necessarily vary in pressure to exceed 3 to 5 pounds, and in most cases governors set to furnish 10 to 15 pounds pressure will furnish an ample margin of supply. The general distributing conditions in any town are greatly bettered by establishing a constant initial moderate pressure. Perhaps the greatest benefit is found in the action of the house regulators, the valves of which will hold true much longer when not exposed to extreme ranges of pressure. For a suitable reducing governor for work of this character only a simple construction is required. The controlling diaphragm is acted upon directly by the gas pressure and balanced by a weight. Operation within a limit of 1 pound is entirely satisfactory, and may be depended upon. These governors should be located in well constructed pits and provided with by-pass.

Extra Large Steel Mains.

Beginning with the 8-inch size, steel pipe is manufactured in more than one weight, and in the larger sizes there is much choice in this respect for the pipe line builder. In addition to what is strictly known as pipe, there are also grades of tubing and casing in which the thickness and weight are still further reduced. Casing is also manufactured in small diameters and many sizes. Much large pipe lighter than standard weight is safe to lay with screw joints. The lighter weights of 8 inches and 10 inches are often chosen for pipe lines and laid in this way. From 10 inches up, however, practice favors the use of plain end pipe jointed entirely with couplings of the Dresser type. This construction is generally found cheaper and safer in large diameter pipe work and there is of course no option where the lighter weights of tubing or casing are used. There are also special joints on the market of which the Matheson may be mentioned as typical.

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For extended experience along these lines we must necessarily go to natural gas practice in which practice pipe of the character mentioned has been mostly used, and although these special weights and methods of construction are of growing interest in our own practice, an extended discussion is probably beyond the scope of this paper. The following observations, however, for which the writer is indebted to Messrs. Battin and Wishart of the Indiana Lighting Company, will be found of interest.

"The whole tendency now-a-days in high pressure natural gas work is to use light pipe and long lengths. The last 10 inch pipe we laid, namely 110 miles, a few years ago, was only 28-pound pipe and the lengths must have averaged 28 feet. What is often used is the same as lap welded casing, which for pipe having an outside diameter of 10 inches weighs only 21.9 pounds per foot. Nearly all natural gas lines are laid using this casing, which in the larger sizes is always measured on the outside diameter. Natural gas companies use this casing often on small lines such as 3 inches and 4 inches, and you frequently run across lines of what seems to us odd sizes; for example, 6⅝ inch casing and 5¼ inch casing. Even old boiler tubes are used for such lines and new boiler tubes are bought for the purpose. One of the reasons why such thin pipe is used for natural gas is that natural gas is generally expected to be a temporary affair and lines are put in for a comparatively short expected life.

"This casing you will notice has a much thinner thread than ordinary pipe and would pull apart very easily from contraction and expansion, so that on pipe as thin as this it would not be feasible to use ordinary screw couplings, and consequently Dresser couplers or similar couplers are nearly always used on these lines. Companies where the pressure is heavy enough to make it seem desirable to use something a little heavier than standard lap welded casing, adopt tubing sometimes which is heavier than casing, but which is lighter than the standard pipe, which for example for the 10 inch

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is made no lighter than 32 pounds per foot, and which is also made in 35 and 40 pound weights. Even in the case of the heavier pipe, however, they consider that it is not only a great deal cheaper to lay the pipe with couplers than to use screw pipe, but there are many less leaks at the start and the pipe remains tighter and there are practically no cases of pulling apart, such as is the case with the screwed couplings, from expansion and contraction especially when the frost goes down in very severe weather. These lines are generally laid just underneath the surface of the earth, seldom having more than one foot or so of covering unless the pressure is such that they have to be weighted down with more earth to prevent them from raising out of the ditch, and hence the frost undoubtedly surrounds the pipe every winter. Under such conditions screwed pipe would break in many places. On these lines a very light coupler is used rather than the heavier type of sleeve.

"For artificial high pressure lines we would not care to use these very light pipes, although we would not use a screwed coupling in any case for large sizes.

"Comparing the Matheson joint with Dresser or similar couplers, we may note that it takes only half the number of gaskets, there being only one gasket to a Matheson joint. Even this is not being used in the majority of cases, because Matheson joints are generally made up with lead caulked, the same as with cast iron pipe; but the result is just the same as it is with lead joints with cast iron pipe. They will not remain tight even a short while and no matter how many times you recaulk them, they are leaking again after a very short time.

"Now the Matheson joint pipe is no worse than cast iron pipe in this respect when made up with lead joint only; but where a reinforcing gasket is used the Matheson joint is tight at the start and remains tight. In fact we had our best results where we did not use lead at all in the joints of Matheson pipe, but simply had the shape of the bell of the Matheson pipe made such that there was only a narrow space at the mouth

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of the bell, and the mouth of the bell was flared out to receive the gasket. From our experience we were very careful to get the gasket specially adapted for the particular work in hand and by watching it carefully and taking it up with the Rubber Company's experts, we were able on one line we may mention to get joints which remained absolutely tight until the line was taken up after 6 years use. Our experience rather favors the use of coupler pipe or Matheson joints instead of screw joints on all pipe 6 inches or larger."

In conclusion the writer desires to make acknowledgment of the valuable assistance he has received from his business associates. Adequate presentation of so comprehensive a subject has been found difficult within the limits prescribed but it is hoped that a discussion will be stimulated that will serve to amplify and improve the various details suggested.

Mr. G. I. Vincent then presented his paper on Street Main Standards.

STREET MAIN STANDARDS.

Abstract.—A set of questions was sent to 204 companies asking their practice as to material and methods in laying street mains. From the replies received, the following information was compiled.

Cast Iron Material.

Standards.—58 per cent. have adopted the A. G. I. 1911 standard, 6 per cent. use American Water Works, 19 per cent. American Gas Light Association of 1898, 7 per cent. their own standard and 10 per cent. had no standard.

Specials:—Some plants use spigot fittings for cut-outs, and bell fittings for line work. Up to and including 12 inches it is recommended that all bell fittings be used, and that bushings be used instead of reducers, and that full size as opposed to reducing openings be left at intersections.

Line drip pots are universally used. The use of a 1¼ inch pumping line for the drip is recommended. It is suggested that the pumping line set-off to the curb has several advantages over the pumping line run straight up under all conditions. A heavy adjustable cast iron box is the best type of cover over pumping points.

Valves are usually used on low pressure work in dangerous lo-

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cations only. These should be protected by a brick manhole with substantial iron cover.

Laying Data:—The universal practice is to lay the service mains about 4 feet from the curb; this does not, however, necessarily apply to the larger supply mains. Mains in Southern cities are generally laid shallower than in Northern. Two Northern cities lay at over six feet. It is suggested that the advantage of going to excessive depth to insure being below frost line is more than off-set by its disadvantage. Also that mains laid shallow are undesirable because of modern deep pavement and difficulty of grading of services. The suggested best depth is from 3 feet to 3½ feet of cover regardless of climate conditions. An allowance of ¼ inch in 2 feet will insure satisfactory drainage.

Although the majority of companies lay their pipes on bare earth, some of the largest companies use blocking as a standard practice. The writer believes that if the ground has not been disturbed, the pipe will be better supported than if laid on blocks. Where the ground has been filled or unusual conditions exist, blocking alone will not suffice to support the mains properly. With pipe of 16 inches or larger, blocking is of value in aligning the heavy lengths of pipe, two blocks being laid back and two blocks in front of each bell. As in smaller mains, this blocking is not adequate to support the mains properly except on original soil.

It is not necessary to protect cast iron pipe against corrosion except in soil containing corrosive material, in which case a bed of clean clay 6 inches thick around the pipe is sufficient protection; and but few plants take precautions against electrolysis, and these by some method of bonding.

Eighty per cent. of the companies test all joints before filling, 9 per cent. part of their mains (the larger pipes as a rule), and 11 per cent. do not test at all. The suggested best practice is to test all low pressure joints below 16 inch at working pressure, and larger mains at 5 pounds pressure, using soapsuds and not depending upon the gauge. Cast iron pipe carrying pressures higher than the recognized low pressure should be tested with soapsuds at a pressure not less than twice the maximum to which the main is to be subjected.

Twenty-three per cent. of the companies reporting use bags only, 66 per cent. use bags and stoppers and 11 per cent. stoppers only.

The methods adopted to prevent freezing over bridges, etc., is to enlarge the exposed pipe by two sizes. It is suggested that the best practice is to enlarge the pipe, but leaving open the question of increase in diameter.

From consideration of all replies received, the best practice as to

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maximum hole allowed to be tapped in each size main is 1 inch for a 4-inch pipe, 1¼ inch for a 6 inch, 1½ inch for 8-inch, 2 inches for 10 and 12-inch, 2½ for a 16-inch, 3 inches for a 20 and 24-inch pipe and 4 inches for all sizes larger.

In regard to ditching and filling, the replies indicated that ditching by piece work is satisfactory, and that machine trenching is generally unsatisfactory in urban work and if practiced in suburbs should be by contract only. If ditches can be filled lightly, the cheapest way is to tamp around the pipe and complete the filling with a horse or motor scraper, afterwards flushing with water. Brief reports on machine tamping show it to be satisfactory.

Jointing Data:—6 per cent. of the companies use lead joints, 9 per cent. cement joints and 85 per cent. both. Lead wool is used to some extent by a few gas companies and reports upon it are favorable. For large mains or large jobs of small pipe, machine caulking is economical both as to operating cost and quality of work. Untarred long-fiber jute yarn free from grease is suggested as best for both lead and cement joints.

Any high grade Portland cement may be used for joints, and no other material except lead is used, although one company used ground-joint pipe. Lead joints are used by some companies in certain locations, as at intersections, at intervals along lines of cement joint mains, and on large pipes. There is believed to be no merit in lead joints in the first two cases, but many large companies are giving up the use of cement on large pipes. The writer believes that cement joints in standard bells should not be used on any pipe larger than 12 inches.

The objection to cement joints on large mains is that the joint is weaker than the main. The shearing stress to which a 30-inch pipe is subjected is excessive, and when other stresses are added, it would seem to be mere accident if the cement joints with standard bells would remain tight.

Another joint which has been used to some extent is a cement joint made in the usual way with the cement trimmed out evenly to the back edge of the lead ring. A lead joint is cast in and caulked, or a lead wool joint is caulked in. The writer has done a good deal of repair work on this principle with no subsequent leakage, and believes that there is no reason why these joints would not be satisfactory for new work. Moreover, these joints cost less than cast lead and much less than lead wool.

The ordinary forms of cast iron joints cannot be depended upon for pressures higher than usual and up to 5 pounds. In this case, clamps should be used over the joints, using an asbestos gasket.

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STEEL MATERIAL FOR STREET MAINS.

Low Pressure Work:—Although about half the companies use steel pipe for low pressure work in special cases, the comparative mileage is very small. About half of the companies specify wrought iron pipe in place of steel. Genuine wrought iron pipe commands a premium of about 15 per cent. and its value is not apparent. Spellerized steel pipe is probably as durable as wrought iron. As full weight pipe only is now rolled, it is no longer necessary to specify it.

The smallest size of cast iron pipe which should be laid under any circumstances is 4-inch on account of the structural weakness of smaller sizes. Two of the largest companies lay no cast iron pipe less than 6-inch and another stops at 8-inch. It is believed that 4-inch is ordinarily substantial enough for urban work with the possible exception of the congested districts in larger cities.

The life of steel pipe in neutral soils is as indefinite as cast iron. A wide range of coating materials is used, 5 per cent. of the companies replying specifying Hickenlooper coating. 7 per cent. asphalt, 12 per cent. red lead and oil, 32 per cent. tar, 2 per cent. galvanized, 9 per cent. various commercial preparations and 33 per cent. no coating. (It is not believed that any of the coatings named will be satisfactory under all conditions, and a number of engineers believe that any plastic coating applied by brushing or dipping might profitably be omitted.)

The various methods used to exclude moisture from the pipe are: (1) A plastic coat applied by dipping or brushing; the value of this is questionable; (2) Combination of plastic protection and rubber; this is superior to the other and if properly applied should add to the life of the pipe. (3) Plastic coatings baked on; this is reported as satisfactory if continuous. (4) Enclosing the pipe in boxing filled with pitch or a mixture of sand and pitch. (This will afford complete protection.) (5) Enclosing the pipe in a box filled with cement mortar. (This is also effectual if properly applied.)

The best material for underground fittings for steel pipe is the extra heavy galvanized recessed fitting.

For repair work on low pressure steel mains the standard cast iron split sleeves with cement joints are satisfactory. (Enough replies were received to throw doubt on the efficiency of rubber gaskets, and asbestos has been found a satisfactory substitute.)

Practice varies between white lead, graphite, Portland cement and oil, and different commercial preparations for pipe joint cement. but red lead is recommended.

The depth of laying, advisability of blocking, and use of valves should

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be as with cast iron; no provision for expansion is necessary; testing with soap suds under gas pressure is satisfactory; the majority of the companies make their drips up with pipe fittings which is satisfactory. Tapping steel pipe is poor practice. In laying, tees looking up should be put in for the known services, and the standard cast iron split tee should be used for subsequent connections.

High Pressure Work—Pipe Lines:—The general construction is similar to that of low pressure steel pipe. Sixty-four per cent. of the companies use steel, the rest iron; none use extra heavy. Seventeen per cent. of the companies do not coat their pipe, and the rest are divided among the coatings mentioned for low pressure work. (One company tests the soil for corrosive qualities.) The same rules are followed as to fittings, pipe joint cement, etc., as in low pressure steel lines. (Although 74 per cent. of the companies use expansion joints, there seems to be no reason for doing so except in exposed mains subjected to a wide range of temperature where buckling might occur.)

Nearly all the companies use valves on pipe lines at intervals of from 500 feet to a mile. Intervals of a mile is suggested as being sufficient, (double iron gate, inside screw with recessed hubs being recommended.) Many of the companies report trouble from leaky valves due to accumulations on the seats, and it is suggested that two valves be installed at each location in a substantial brick man-hole.

Pipe lines are almost universally laid at a depth of from 2 to 2½ feet, (which has proved satisfactory.)

It is suggested that the pipe be tested with air at twice the maximum working pressure, when bad leaks can be detected by the sound; all fittings should be tested with soapsuds. (A gauge will indicate small leaks, only after the pressure has been on for an unreasonable length of time.)

The majority of companies use no drips on high pressure lines, the moisture eliminators making these unnecessary. It is recommended, however, that tees be installed at low points. The pressures carried vary from 5 to 75 pounds with an upward tendency, and it seems that pressures may be raised to 100 pounds with economy and advantage.

The accepted method of repairing leaks is to use a split leak clamp made for the purpose. Where only the thread is leaking, a satisfactory and permanent repair can be made by caulking copper wire into the recess and peening over the head of the fitting.

High Pressure Town Lines:—The earlier practice was to reduce the pressure in town lines to holder pressure, usually by discharging into a holder and distributing from that. Later district governors took

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the place of the holders, and after that the practice was to carry 2 or 3 pounds on the town lines and equip the individual consumers with governors. At present a number of towns are being carried at full line pressure. (While this has proved safe and satisfactory, the advantages are not apparent enough to warrant its recommendation for universal adoption, and but 2 pounds is suggested as a maximum, with full line pressure for scattered villages and hamlets.)

There seems to be no particular connection between the number and location of valves on the town lines and the pressure carried. It is suggested that where full line pressure is carried on town lines, the same system of valves are used as on the pipe lines. Where the towns are on moderate pressure, say 2 pounds, it is only necessary to use valves in the special locations prescribed for low pressure systems.

Service connections are universally made with saddles and lead gaskets, the pipe being then run from a corporation cock. It is suggested that service shut-offs be installed outside the building on all high pressure services (whether the pressure is 2 pounds or 30 pounds).

Where the towns are on district governors, the safety blow-off at the governor will afford sufficient protection. Where full line pressure is carried, each consumer should be provided with a safety seal and blow-off of ample size and fairly protected against stoppage.

General Policy.

It is the universal practice to overhaul or inspect mains on streets which are to be paved; details of practice vary widely, but it is suggested that all the mains be barred over, all services examined at the house and all drips be examined. No pipe under 4-inch should be allowed to remain, and mains of this size should be examined for service taps.

All the larger companies make some inspection of their mains ranging from a continuous daily line walk of mains down to periodical inspections of certain locations. (It is not believed possible to standardize practice in this regard, but a continuous patrol of high pressure and a periodical inspection of low pressure lines seems advisable.)

Object.

The object of this paper is to present to the Institute the best practice in street main work.

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Method of Preparation.

In order to secure the practice of as many of the gas companies as possible in this country, a list of questions was prepared, copy of which is attached to this paper, and this list of questions, with accompanying letter, was sent to 204 companies.

The replies received were carefully summarized, and from the material so obtained and from additional information obtained by correspondence and discussion, that practice, which appears to the writer to be the best, has been selected. Under some headings the practice of the majority has not been offered as the best.

It is obvious that there is necessarily a wide variation in the methods used by various companies throughout this country, but a study of the data indicates that the variations are not usually due to geographical locations or climatic conditions. In other words, if there can be shown to be one best practice in most of the items into which the subject is divided, then there is no apparent reason why this best practice cannot be adopted by all.

It is proposed to discuss each item briefly and to present a suggestion for standard practice. This is drawn usually from the data received. When from other sources it is so stated.

First Sub-Division.

Cast Iron Material.

STANDARDS.

Of all the replies received 58 per cent. have adopted, or are adopting the American Gas Institute Standard of 1911 for Pipe and Specials. Of the remainder 6 per cent. use American Water Works, 19 per cent. American Gas Light Association of 1898, 7 per cent. their own standard and 10 per cent. stated that they had no standard.

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Of the variation from the American Gas Institute and other standards those having reference to the depth of bell are the most numerous. This will be discussed later under joints. It is obvious, from the fact of its having prompt adoption, that the American Gas Institute standard has met with universal satisfaction and no further discussion of the subject seems necessary.

SPECIALS.

Bell and Spigot Fittings.—The question, as to whether all bell tees and crosses or whether bell and spigot were used, was asked because many works have adhered to the old practice of using spigot fittings, consequently accumulating a large stock of spigot pieces of pipe. There seems to have been no possible excuse for this practice, though a number of the smaller plants still seem to be using the spigot fittings.

Some answers state that spigot fittings are used for cut-outs and all bell fittings for line work. If only bell fittings are carried in the smaller sizes, only one more joint is required for cut-out work than if spigot fittings are used, and the stock required to be carried is cut in two. The cost of the one additional cement joint is less than the cost of carrying the additional stock. For large size mains, 16 inches and over, it is customary in the majority of works to order their fittings as required for a particular job and the question of stock does not enter.

The suggestion is, therefore, that up to and including 12 inches, all bell fittings will answer every purpose for all work and will represent a saving in the storeroom costs over the slight additional cost of handling the cut-out work.

Reducers or Bushings.—It was interesting to find that many plants are still using reducers, as for normal work bushings are as good and are certainly cheaper, both in first cost and in the cost of carrying the storeroom stock. The same line of discussion can be followed as with specials in that, in 16 inches

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and over, jobs may be considered special and fittings ordered as required, while in 12 inches and under, constant stocks would be carried in the average works.

It is, therefore, suggested that the use of bushings be substituted for reducers for 12 inches and under.

Full Size or Reducing Fittings.—The question of full size or reducing openings at the intersections met with the almost universal response that full size openings were left. There seems to be no question that this practice is the better in mains up to 12 inches, and again in the larger sizes the individual jobs can be determined separately.

Drip Pots.—The line drip for permanent installation has superceded all other types. The only situation where a side pot is required would be in a special case where very large capacity is necessary, when a special construction would be designed. The only possible advantage of the side pot drip is that it can be opened for cleaning or inspection without shutting down the line. It is believed that the necessity for opening a drip for such purposes practically never arises in modern distribution practice.

The recommendation is that the line pot drip be universally adopted for all sizes, except in the very special cases above mentioned.

Size of Pumping Line.—The size of the pumping line from the drip pot varies all the way from ½ inch to 1½ inches, the majority using 1 inch.

The writer has adopted 1¼ inch as standard for the reason that the pipe is stronger, has thicker walls to resist corrosion (which is a very important point with pumping pipes), and adds very little indeed to the cost of installation. The top of the pumping pipe should be finished with a 1¼ x 1 inch reducer with the 1 inch plug lubricated with heavy oil only.

Off-set Pumping Pipes.—The plants having the larger percentage of paved streets use pumping pipes running straight

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up from the drip pot. The plants having a high percentage of unpaved streets use off-set pumping pipes. This could have been anticipated.

It is interesting to observe, however, that there are important exceptions to the first rule, and in conjunction with several other engineers, the writer believes that the pumping pipe off-set to the curb has a number of advantages over the pipe running straight up, under all conditions. The off-set pipe, if in unpaved streets, may be marked by a substantial post at the edge of the parking to facilitate locating in bad weather. If in paved streets, the box is not subject to anything like the wear and tear of a box in the roadway. If settlement takes place so that the lid of the box actually rests on the pumping point, no subsequent danger would arise, while if in a roadway under the same conditions, a broken pumping pipe or drip pot plug would probably be the result. The pumping of the drip will not require the obstruction of the roadway by the drip wagon or other apparatus, if the pumping point is at the curb. The objections to the off-set pumping pipe are that the drip cannot be "rodded" but the contents of the drip can be obtained just as readily by the use of a pressure gauge. The disadvantage of the off-set pipe is the fact that its installation costs a trifle more than the straight up, and also the greater exposure to corrosion where running under the curb to the sidewalk or parking.

The writer believes that the advantages of the off-set pipe more than outweigh the straight up, and suggests it for standard practice.

Pumping Point Cover.—The type of box generally accepted to be placed over the pumping points of drips is a substantial cast iron box with a square or round loose cover and with an adjustment as to length. The fastening of the covers on with screws is a practice not to be commended. After setting the box to grade it should be filled with sand and tar. There seems to be no reason why this type of cover should not be as standard as street main specials and it is, therefore, suggested

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that it be standardized and added to the cast iron pipe and special standards.

Valves.—With the exception of three companies, street main valves are not used in low pressure cast iron work except at the ends of bridges or other locations where the mains might be destroyed by outside sources. There seems to be no reason for the use of valves on low pressure mains except in these dangerous locations.

Valve Covers.—The valves should be covered with a substantial iron cover on a brick manhole so that access to the valve for packing, oiling and testing can be readily obtained. The use of small covers over active street main valves is not to be commended.

LAYING DATA.

Location.—The question as to the location in the roadway was asked to determine if a location at one side of the center of the street was not the universally accepted location for the gas main. On account of the varying condition of other underground constructions it is of course impossible to suggest standardizing a location. The universal practice, however, is to locate the gas mains at such a point that they are about 4 feet from curb lines or will be about 4 feet from a curb to be subsequently installed. This applies to the smaller service mains and not necessarily to the larger supply mains.

Depth.—The depths at which mains are laid seem to have no general connection with the climate. One reply is characteristic of what is apparently good practice: "Mains are laid 3 feet 6 inches deep because this is the best location with reference to other underground structures, the frost going down to 7 feet."

While it is true that the majority of plants located in the south lay their mains shallower than those in the north, there does not seem to be any particular reason for this except that it was apparent that most of the southern plants that laid

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shallow were those in which other underground structures were not nearly as extensive as would be found in northern cities, of the same size. The writer is of the opinion that, if it were practicable to lay gas mains at such a depth, that under no conditions would they be reached by frost, it would be advantageous from the standpoint of safety to the mains. In other words, mains below any possible frost line would be less likely to be broken by strains set up by temperature changes than mains within the frost depth. This one advantage, however, would scarcely justify the greater depth. One large northern city lays its mains at a depth of 6 feet and another 6 feet 6 inches, but the majority adhere to a depth of 3 feet 6 inches and 4 feet. Depths of only 2 feet are undesirable because of the increasing use of deep pavements and heavy paving machinery and also because of the difficulty of properly grading services to the shallow mains.

The suggestion is, therefore, that under normal conditions, the mains are laid from 3 feet to 3 feet 6 inches measured from the grade line to the top of the pipe. This conclusion drawn from the data differs from the opinion given on pages 382 to 384 of the *Catechism of Central Station Gas Engineering in the United States.*

Grading.—The question as to grading of the mains was evidently not clearly understood, as gradings were given varying from 3 inches in 12 feet to "as near level as possible." In good street main construction an allowance of ¼ inch in 12 feet will insure satisfactory drainage.

Blocking.—The widest variation in opinion was in the question of laying on bare earth or on blocking. While the majority of the companies lay on bare earth, if the average is weighted by miles of main in use, the advantage is slightly in favor of blocking. In other words, some of the largest companies use blocking as a standard practice.

The writer has discussed this matter with a number of leading engineers and is now of the opinion that the advantages in favor of blocking are not sufficient to warrant their

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universal use as a standard method of construction. Careful main laying requires a true bottom to the ditch and if the ground is virgin soil the length of main will be supported better than if laid on blocking. Where filled ground or unusual conditions exist blocking alone will not suffice to properly support the mains. A special design would necessarily have to be made for the particular job by the man responsible.

The above applies without qualification to mains 12 inches and smaller. In larger mains another question is involved and that is the use of blocking to insure satisfactory alignment in laying the heavy lengths of pipe, the idea being to insure the weight being taken off the joints. If sufficient blocking is used here, the additional expense involved is justified for laying mains 16 inches and over and the following schedule is suggested:

TABLE NO. 1.

Size main in.	Size of blocking Length in.	Width in.	Thickness in.
16-20	24	12	3
24-30	30	12	4
36-48	36	12	4

Two blocks to be laid back of each bell and two blocks in front of each bell, making four blocks to each length of main. As in smaller mains, this blocking is not adequate to properly suport the mains except on original soil.

Protection against Corrosion.—It is not necessary to protect cast iron pipe against corrosion except in filled soil, which is known to contain corrosive material, in which case a bed of clean clay 6 inches thick completely surrounding the pipe is sufficient protection. It is believed that the plants that use cast iron pipe coated with tar or bituminous compounds are wasting the money spent on the coating.

Electrolysis.—It is not proposed to go into the question of electrolysis as it has been thoroughly discussed in a number of complete articles in the technical journals. Of all the answers received only a very few plants used any method of

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protection and these by some method of bonding. The advantages and disadvantages of these methods have been fully discussed by thoroughly competent engineers and it is not necessary to take up the matter again.

Testing Joints.—Eighty per cent. of the companies tested all joints before filling, 9 per cent. tested part of their mains, the smaller sizes as a rule being passed without testing, and 11 per cent. do not test at all. Opinions were equally divided as to the relative merits of air and gas pressure and the dependence on soap-suds or on a gauge by those companies that tested their joints. The suggested best practice is as follows:

All joints for low pressure up to and including 12 inches to be tested with soap-suds under the pressure of the gas only. All mains for low pressure 16 inches and over to be tested with air pressure at 5 pounds using soap-suds and not depending on the gauge. All cast iron carrying higher than the recognized low pressure to be tested with air pressure and soap-suds at a pressure not less than twice the maximum pressure to which the main is subsequently to be subjected.

Mention should be made, however, of the fact that there is one notable exception to the companies that test joints. This company uses no jointing material for cast iron mains except lead wool, and does not test the joints at all.

Bags and Stoppers.—The perfection of the street main stopper has evidently commended itself to a large number of companies. Only 23 per cent. of the answers received use bags only, 66 per cent. use bags and stoppers, while 11 per cent. use stoppers exclusively. That stoppers are satisfactory for all pipe except some very old imported cast iron or pipe which is partly filled with foreign material is evidenced by the 11 per cent. of the plants which have no bags whatever in stock. This is of course not offered as standard practice.

Prevention of Freezing.—The method adopted to prevent freezing over bridges and exposed places is by enlarging the pipe, using two sizes larger than the connecting main. The writer does not believe that this is sufficient enlargement in extreme climates unless the gas is partially dehydrated before

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reaching the point of exposure. However, the opinion of the best engineers seems to be that it is the only method of insuring against frost stoppages and except under the most unusual conditions, protective covering is not satisfactory. It is suggested, therefore, that the best practice is the enlargement of the pipe, while it is not possible to offer a suggestion as to the amount of increase in diameter.

Maximum Tap Hole.—The maximum size hole allowed to be tapped in each size main met with a wide variation in response.

One company tapped 4 inch mains as large as 2 inches without a sleeve. From consideration of all answers received the following schedule is offered as the best practice:

TABLE NO. 2.

Size of main	3 in.	4 in.	6 in.	8 in.	10 in.	12 in.	16 in.
Maximum tap hole allowable	¾	1	1¼	1½	2	2	2½

Size of main	20 in.	24 in.	30 in.	36 in.	42 in.	48 in.
Maximum tap hole allowable	3	3	4	4	4	4

In 3 inch mains if the ¾ inch hole is tapped for a service connection a split sleeve should be put on. Any hole tapped in a 2 inch main should be subsequently covered by a sleeve. It will be noted that 1 inch is the largest size allowed for 4 inch pipe although the majority of companies allowed 1¼ inch.

The writer offers this largely from his own experience in having 4 inch mains broken at 1¼ inch taps. It will be understood that if any larger hole than that given in the schedule is desired that split sleeves or the proper fittings are to be used.

Ditching and Filling.—The 7 questions covering the subject of digging and filling ditches were used to secure general information more than with any idea of establishing a standard. It is obvious that the method employed in a town built on solid rock would vary widely from that of a town founded on sand. The summation of this data is as follows, all applying to soils which can be removed with spades or picks and shovels.

Ditching by piece work under normal conditions is satisfactory and economical.

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Machine ditching is generally unsatisfactory in urban work. In suburban work if used at all it should be by contract.

If ditches can be filled lightly as is allowable in the outlying sections of many cities the most economical method is to tamp around and over the pipe and fill the balance with a scraper either with a horse or motor. The subsequent flushing of this lightly filled ditch will make a fair job but can only be used where water can be secured at an economical figure.

The brief reports on machine tamping show it to be satisfactory.

The filling of excavations with sand is said to be required by some municipalities. There is no ground for this action as applied to well operated gas companies.

JOINTING DATA.

Lead Joints.—Six per cent. of the companies use lead joints, 9 per cent. cement joints and 85 per cent. both.

The schedule given below shows the proper depth of cast lead in lead joints, all based on American Gas Institute standard bells. This is not an exact average of all data submitted.

TABLE No. 3.

Size of main	3 in.	4 in.	6 in.	8 in.	10 in.	12 in.	16 in.
Depth of lead...	1.5	1.5	1.75	2.00	2.00	2.25	2.25

Size of main	20 in.	24 in.	30 in.	36 in.	42 in.	48 in.
Depth of lead...	2.25	2.5	2.5	2.75	2.75	2.75

Lead Wool.—Lead wool is being used to some extent by a few gas companies and the reports on its efficiency are very favorable. The exclusive use of this material by one large company has been mentioned. The theory of the lead wool joint is apparently sound. There is not sufficient data at hand to make a specific suggestion but the matter will be referred to again under the discussion of jointing material.

Hand or Machine Caulking.—For small jobs the expense of moving a portable machine for caulking is so great as to render its consideration out of the question. For large mains or extended jobs of small mains the machine hammer is more

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economical, both as to actual operating cost and in the perfection of the finished work.

Yarn.—Untarred dry jute packing with long fiber and free from grease is suggested as the best material for packing both lead and cement joints.

Cement Joints.—The almost universally accepted method of making cement joints is to drive one rope of packing to the back of the bell with a heavy yarning iron and hammer, then to fill the joint with neat cement properly mixed; drive another rope of packing with yarning iron and hammer, and point the face of the joint. The variations from this method are very few. One variation consists of making a joint with a spiral of yarn extending from the back to the front of the bell and holding in place a spiral of cement. It is incredible that this joint could be made tight. Another variation consists of alternate layers of cement and yarn. This is undesirable because it has been found that the maximum amount of cement possible should be used in a joint.

Brand of Cement.—Any high grade Portland cement may be used for joints. The use of imported cement seems to have been almost entirely given up. A medium setting cement rather than a quick or slow setting is desirable. If any company is using the new extra fine German Portland cement, there was no report on it.

Other Jointing Material.—No other jointing materials except lead and cement are used by any of the companies answering the questions. One company uses a special brand of ground-joint pipe.

Lead or Cement.—Lead joints were used in part by a number of the companies at certain locations such as at intersections, at various intervals along lines of cement joint mains, and on large mains.

There is believed to be no merit whatever in using lead joints for the first two cases, but in the third, that is, in large mains, many of the larger companies are discontinuing the use of cement. The sizes above which lead joints are stated to be more desirable than cement, vary from 8 inches to 30 inches.

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The writer drawing on his own experience and the experience of a number of other engineers ventures the assertion that cement joints on cast iron mains 16 inches and over are not to be depended upon. This means mains laid with all known precaution in making cement joints and using American Gas Institute standard pipe and specials. In other words, it is offered as standard practice that cement joints be made only on mains up to and including 12 inches and that over 12 inches either a special bell or a special joint be adopted.

The reason for failure in cement joints in the larger size mains seems to be that the joints are not as strong as the pipe itself. There have been some experiences in cement joint mains in the smaller sizes where the mains have broken very near the bells where the cement joint remained intact. In large mains the joints leak before the mains give way. Apparently contraction alone will not break any gas main unless it is aided by some other lateral strain, unusual condition or flawed pipe. With a variation of 100 degrees F. in a bar of cast iron held rigidly at the ends, the calculated factor of safety against breakage is about 2½, and 100 degrees F. is at least twice the maximum variation in temperature which might be expected in any underground main. The large mains resist lateral strains to a much greater extent than small mains, but the difference in temperature between the top and bottom of a large main is probably sufficient to set up serious stresses in the joints.

It occurred to the writer that it might be possible to calculate theoretically the stresses to which joints are subjected due to change in temperature in the mains.

For the purpose of making the calculation a 30 inch main with standard American Gas Institute bells was assumed to be laid in the climate of Des Moines, Ia., with all possible care, and that the main was subjected to changes in temperature such as are known to take place under ground in that climate.

Certain assumptions necessarily had to be made, as a basis

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of the theoretical calculation, but these assumptions, it is believed, are well within the practical possibilities.

It was found that the combined shear on the joints in the straight pull and bending moment, due to changes in temperature and the difference in temperature at the top and bottom of the pipe, was 112 pounds per square inch as a maximum. This shear is two and a quarter times the shear allowed in concrete steel work for the maximum safe contact strength of steel and cement. In other words, the shearing stress to which the 30 inch joint would be subjected under these conditions due to temperature alone is excessive and when there are added to this stress, other stresses due to forces outside of the main, it would seem that it would be a mere accident if 30 inch cement joints with standard bells would remain tight.

Following out this calculation the depth of bells necessary to have sufficient shearing strength for the contact between the cement ring and the iron of the bell or spigot was calculated in the 30 inch main and based on this calculation the following schedule is offered as the proper depth for bells of the larger size mains where straight cement is used.

TABLE No. 4.

Size of main	16 in.	20 in.	24 in.	30 in.	36 in.	42 in.	48 in.
Depth of special bell for cement joints, inches...	5.75	6.25	6.75	7.25	7.25	7.25	7.25

Another joint which has been used to a very large extent in repair work and to some extent in new work is the combined lead and cement joint.

This joint is made by making the cement joint in the usual way including driving the cement. The cement is then trimmed out evenly so that the front face of the cement is at the back edge of the lead ring, which in American Gas Institute standard is 1¼ inch from the face of the bell. After allowing the cement to set for 24 hours a lead joint is cast in front of the bell and caulked, or a lead wool joint is caulked in.

This joint would be identical with cement joints which have been repaired, by cutting out the front yarn and the necessary

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cement on the old joint and casting and caulking a lead joint in front of it.

The writer in common with many other engineers has done a great deal of this repair work on 16 inch mains and over. It is cheaper than using a special clamp and in experience extending over the number of years there has been absolutely no subsequent leakage in the joints so repaired. The possible reason for the efficiency of this joint is that the cement ring holds the joint rigid, or rather confines its movement to extremely small amounts, and the lead ring has sufficient elasticity to remain tight under the very slight movement.

The point is, therefore, that if the joints have been found satisfactory in repair work, there is no apparent reason why they cannot be used satisfactorily for new work. The approximate cost of these joints and the cost of all lead joints with the standard bell and depth of lead given in Table No. 3, and also of all cement joints with the special depth of bell given in Table No. 4, is as follows:

TABLE NO. 5.

COMPARATIVE COSTS OF VARIOUS JOINTS.

Size of main	Lead wool		Cast lead		Combination cement and cast lead		Cement with Special deep bell	
In.	Cost	Per cent.	Cost	Per cent.	Cost	Per cent.	Cost	Per cent.
16	$2.11	100.0	$1.77	83.8	$1.20	56 9	$0.56	26.6
20	3.14	100.0	2.61	83.2	1.72	54.8	0.88	28.0
24	4.27	100.0	3.40	79.6	2.21	51.8	1.09	25.6
30	5.21	100.0	4.16	79.7	2.70	51.8	1.63	31.2
36	6.30	100.0	5.02	79.5	3.26	51.7	2.15	34.1
42	7.27	100.0	6.24	86.0	3.79	52.2	2.58	35.5
48	8.34	100.0	7.12	85.4	4.36	52.2	3.05	36.5

NOTES.

1. The costs are for labor and material for joints only and are approximate.

2. The per cent. columns show the per cent. of the cost of the lead wool joint, which is the highest.

3. Cost of additional iron in the pipe is included in the deep cement joint.

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It will be noted that the deep cement joint is cheaper than the combination lead and cement joint and very much cheaper than the all lead or lead wool joint. If, however, it were known that the lead wool joint would remain permanently tight, it would probably be offered as standard regardless of its high cost.

The subject may be summarized for mains 16 inches and over as follows:

Cast lead joints in standard bells usually leak slightly in the course of time.

Cement joints in standard bells will eventually leak more or less badly and the larger the size the greater the leakage.

The combined lead and cement joint in standard bells has been proved by reasonable experience to be satisfactory.

The lead wool joint in standard bells has also been proved satisfactory by reasonable experience.

The special deep bell all cement joint may be satisfactory.

The matter is left open for discussion. What is needed is experience from actual service. Laboratory experiments have not been satisfactory. The writer suggests that from the standpoint of low first cost and probable service, that the most hopeful combination is the special deep bell with cement joints, with lead wool in any of the few joints where a standard bell might have to be used.

The use of lead joints in small mains in very cold or very hot weather is unnecessary because it is entirely possible to make satisfactory cement joints in freezing or torrid weather by taking reasonable precautions.

Clamps.—Where cast iron mains are to be used for moderate pressures, say up to 5 pounds, the ordinary forms of jointing material cannot be depended on. For these pressure mains, clamps should be used over the joints if standard cast iron pipe is used and an asbestos gasket is preferable to rubber.

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Second Sub-Division.

Steel Material for Street Mains.

LOW PRESSURE WORK.

Although about half the companies use steel pipe for low pressure mains at times, it is always for special situations or below certain sizes. The comparative mileage is very small.

Steel or Wrought Iron.—About half the companies specify wrought iron in preference to steel. The mild steel now being turned out by the tube mills is really the so-called wrought pipe and an order for wrought pipe or black pipe will be filled with steel. The so-called genuine wrought iron pipe commands a premium of about 15 per cent. over steel. Its additional value is not apparent. Spellerized steel pipe is probably as durable as the wrought iron.

Merchant or Full Weight.—The leading mills now roll only full card weight pipe so that it is no longer necessary to specify it.

Size in Preference to Cast Iron.—The smallest size of cast iron which should be laid under any condition is 4 inches, and the reference to smaller sizes in the discussion heretofore must be understood to refer to mains which have been laid in the past. For anything smaller than 4 inches, steel pipe should be used because cast iron pipe in 3 inches and less is too fragile to be depended on for underground work. Two of the largest companies do not lay any cast iron less than 6 inches. Another stops at 8 inches. It is believed that the conditions governing these situations are unique and that 4 inch cast iron mains are substantial enough for urban work, with the possible exception of congested districts in the larger cities. This would all come under relaying and it is not possible to imagine such a condition where anything less than 6 inch cast iron would have sufficient capacity, so this size or larger would be used as a matter of course.

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Life of Steel Mains.—The life of steel pipe in neutral soils which remain undisturbed by any outside conditions is as indefinite as cast iron.

Coating.—In the answers to the question as to coating the companies specified a wide range of materials. Five per cent. specified Hickenlooper coating, 7 per cent. asphalt, 12 per cent. red lead and oil, 32 per cent. tar, 9 per cent. various commercial preparations, 2 per cent. galvanized, and 33 per cent. no coating.

It is not believed that any of the coatings named can be depended on to give entire satisfaction under all conditions, and the expressions of opinion from a number of engineers lead to the conclusion that any plastic coating applied by brushing or dipping might profitably be omitted.

The matter has been the subject of much technical literature. The first specific reference to coating wrought pipe for gas service work was Dr. Humphrey's short topic at the 1896 meeting of the American Gas Light Association, published in Volume 13 of the *Proceedings,* page 186. This was the Hickenlooper coating and the reports at that time indicated that it was satisfactory as far as it went. This is undoubtedly true for this coating up to the present time.

The subject has come up very extensively in the last decade with special reference to the coating of steel conduits now extensively used in hydraulic installations, and the conclusion or rather lack of conclusion seems to indicate that the matter is far from settled.

The pipe coating suggested by Mr. von Maur of St. Louis and described on page 318, Volume 6, Part 1, *Proceedings* of the American Gas Institute, is undoubtedly superior to any plastic coverings applied by dipping or brushing. One of the large pipe manufacturers supply a coating of this type consisting of one or more layers of fabric saturated with a bituminous compound wrapped on the pipe, which is first cleaned and dipped. The cost of this covering adds about 1 cent per foot per inch of diameter.

It has been stated many times by competent metallurgical

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engineers, if the metal of the pipe underground can be protected from any contact with air, moisture, acid or electrolytic attack, its life will be indefinitely long. The problem is to supply the protection economically.

A summary of the methods used to exclude moisture, air and acid from the pipe and the probable relative merit of each method are as follows:

First: A plastic coating applied by brushing or dipping. The value of these coverings is questionable.

Second: Coatings consisting of a combination of plastic protection and fabric. This covering is undoubtedly superior to the plain plastic covering and if properly and continuously applied will add materially to the life of the pipe.

Third: Plastic coatings subsequently baked on, in a manner similar to enameling processes. This type of protection has been reported as being satisfactory if it is continuous.

Fourth: Enclosing the pipe in adequate boxing filled with pitch or with a mixture of sand and pitch. This protection if properly applied and remaining undisturbed will afford complete protection.

Fifth: Enclosing the pipe in adequate boxing filled with cement mortar. This also is an effectual and complete protection if properly applied. It is believed that where this method has been used and subsequent failure reported, that the methods used in the original installation were defective. It has the advantage over all other types of protection in that it is practically indestructible.

Fittings.—The suggestion for the best fitting for underground work for steel pipe is an extra heavy galvanized recessed fitting. Standard weight galvanized recessed fittings will be probably satisfactory, but the slight additional cost of the extra heavy makes their recommendation advisable. Dresser fittings or fittings of the Dresser type are neither necessary or desirable for low pressure work.

Repair Work.—For repair work on low pressure steel mains the standard cast iron split sleeves with cement joints are satisfactory.

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Sleeves with Rubber Packing.—Of the comparatively few answers received to this question a large minority were of the opinion that rubber for underground work was undesirable. Certainly this is enough to throw doubt on the efficiency of rubber gaskets and they are, therefore, not recommended. As a substitute, asbestos gaskets are suggested. The use of asbestos gaskets for making gas tight joints in exposed work under the lids of dry lute purifiers and in similar situations, has been found to be satisfactory. The service is probably as hard on the gaskets under these conditions as in an underground main.

Pipe Joint Cement.—Thirty-eight per cent. of the companies use red lead and oil, 26 per cent. use white lead, 4 per cent. use graphite, 4 per cent. use Portland cement and oil, 28 per cent. various commercial preparations. For permanent work red lead in linseed oil is suggested as the best pipe joint cement.

Depth Laid.—The discussion as to the depth of steel mains for urban work follows exactly the same line as for cast iron mains and the suggestion is that they be laid from 3 feet to 3 feet 6 inches deep.

Expansion.—No provision for expansion is necessary.

Blocking.—Blocking under normal conditions is unnecessary. For abnormal conditions the same specifications as for cast iron apply, in that blocking is not sufficient to support the mains in filled ground and a special design should be made. The additional strength of steel pipe should not be depended on to hold up in loose fills.

Testing.—For low pressure work, testing with gas pressure and using soap-suds on each joint is satisfactory.

Valves. The use of valves except in the special locations described under cast iron is unnecessary.

Drips.—The majority of the companies specify a drip made up of pipe and in the absence of specific descriptions this is understood to mean a cross set vertically in the line with a capped pipe extending down from the bottom outlet to form a reservoir and the top outlet equipped with the proper bushing and pumping pipe. This type of drip is satisfactory, and the

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demand is so small that it is inadvisable to have a standard casting made for line drips in 3 inches and less.

Tapping.—Tapping small steel pipe for service connections is poor practice. When a line is laid, tees looking up should be left for the known services and the standard street tee and ell used for the service connection. For subsequent service connections the use of a standard cast iron split sleeve tapped with the proper hole, is suggested. The standard saddle used for high pressure taps is equally good if tapped with a large enough hole. The standard split sleeves, however, would generally be carried in stock.

HIGH PRESSURE WORK—PIPE LINES.

The general construction for high pressure work is similar to that of low pressure steel pipe. To keep the matter collected under each heading, specifications which are alike or similar are repeated.

Steel or Wrought Iron.—Sixty-four per cent. of the companies specified steel pipe, 36 per cent. specified wrought iron. As heretofore stated the advantages of wrought iron pipe as now rolled, over the mild steel pipe of the trade is not apparent. Wrought iron pipe of charcoal iron might be more durable than mild steel, but pipe is not manufactured of this material.

Line Pipe.—Line pipe is universally used for pipe lines. No companies reporting used extra heavy.

Coating.—Seventeen per cent. of the companies do not coat their pipe used in pipe lines. Of the remainder 10 per cent. use the Hickenlooper coating, 14 per cent. asphaltum, 7 per cent. lead and oil, 35 per cent. tar in some form, and 17 per cent. various commercial preparations. One company tests the soil for its corrosive qualities.

Exactly the same line of discussion can be followed for pipe lines as for steel pipe in low pressure work. It is suggested that no coating be used on line pipe except in locations where the soil is obviously corrosive, when protection which is certain to protect should be applied.

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Couplings.—Standard recessed couplings for line pipe are recommended.

Fittings.—Extra heavy galvanized recessed fittings are recommended.

Pipe Joint Cement.—Red lead and oil is used by 43 per cent. of the companies. Those using other compounds are divided; 26 per cent. white lead, 8 per cent. cement and oil, 11 per cent. graphite, 9 per cent. various commercial products, and 3 per cent. none whatever. Red lead is suggested as the best. Its service under exacting conditions has been proved by very extended use not only in the gas industry but in many other arts.

Maximum Pressure on Cast Iron Mains.—The highest pressure carried on cast iron mains by any company is 12 pounds. There seems to be no reason why higher pressures should not be carried on cast iron pipe if the joints can be made tight.

Expansion Sleeves.—Although 74 per cent. of the companies use expansion joints on pipe lines against 26 per cent. who do not, there is no good reason why expansion joints should be used except in exposed mains subjected to a wide change in temperature, which would possibly buckle the main. In underground work expansion joints are not necessary as the lines have an ample factor of safety with a range of temperature of 50 degrees and figuring on the weakest point. This weakest point is at the bottom of the first thread outside of the coupling. The cases that have been reported of lines pulling apart at the couplings or fittings are believed to have been due either to the fact that recessed fittings were not used so that severe corrosion took place at the exposed thread, or that the threads were improperly cut. The use of the straight thread is not recommended Tapered threads carefully cut should always be used.

Location of Valves.—Nearly all the companies use valves on pipe lines at intervals varying from 500 feet to a mile. Under normal conditions it is suggested that intervals of one mile is sufficient to properly care for a pipe line in case of leakage or other repairs.

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Type of Valves.—The all iron double gate, inside screw valve with recessed screw hub is recommended for use in pipe lines.

Leaking Valves.—Many of the companies report trouble from leaking valves on high pressure lines. Two of the leading companies install two valves at each valve location with the idea that it is only necessary to shut down one section of main to repair a valve. The principal difficulty appears to be, not so much in the leaking of the stuffing boxes of the valves, but in the fact that owing to accumulations in the seat the valves do not seat tight.

It is suggested as the best method that two valves be installed at each location and that they be covered with a substantial cast iron cover on a brick manhole so that complete access may be had to the valves at any time.

Depth Laid.—Pipe lines are laid almost universally at a depth of from 2 feet to 2 feet 6 inches and this range of depth is suggested as satisfactory.

Testing.—It is suggested that a line pipe after laying and before filling in should be subjected to an air pressure of twice the maximum pressure at which the line is to be operated. Bad leaks such as a split pipe or fitting can be detected at once by the sound of escaping air. All couplings and fittings should be examined and tested with soap-suds. The use of a gauge for determining the drop in pressure will not detect small leaks unless the pressure is allowed to remain on for an unreasonable time. For example, one mile of 3 inch line pumped to 100 pounds pressure and having a small leak of 2 feet an hour will only drop 3 pounds in 24 hours, while a fall in temperature of only 15 degrees will cause the same drop.

Drips.—The majority of the companies report that they do not use any drips on high pressure lines and there is no apparent necessity for using them.

The installation of moisture eliminators at the outlet of the pumping plant will satisfactorily remove all moisture. It is suggested, however, that tees be installed at the low points on

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all pumping lines and that these tees be located from suitable permanent monuments or property corners.

Pressure Carried.—The pressures carried on pipe lines vary from 5 pounds to 75 pounds. There is a tendency to increase the pressures carried. Experimental and practical data indicates that the pressures may be raised to 100 pounds with advantage and economy where conditions demand.

Leaks Fixed, How.—The accepted method of fixing leaks is to cover the leaking fitting with a split leak clamp made for the purpose. Where only the thread is leaking a satisfactory and permanent repair can be made by caulking copper wire into the recess and peening over the bead of the fitting.

Marking Valves.—Even where the valves are covered with a large manhole there is a possibility of its being covered over by shifting traffic, particularly in the unpaved roads in the open country. The suggested method of marking these is by a post made of 4 inch cast iron pipe set along the fence line, or at a suitable location along the line of the roadway.

HIGH PRESSURE TOWN LINES.

Reducing Governors.—In the larger systems of high pressure distribution the earlier practice was to reduce the pressure on the town lines to holder pressure. Usually this was done by discharging into a low pressure holder and distributing from the holder. In the evolution of the system, district governors were installed in place of holders and gas pressure was still maintained at holder pressure. Another development was to set the district governors at from, say 2 to 3 pounds and equip the individual consumers with governors. At present a number of towns are being carried at the full line pressure.

The objections to this system have all been met in practice and the method has proved entirely safe and satisfactory. The advantages, however, of the full line pressure in the town are not enough apparent to warrant its recommendation for universal adoption.

In the operation of a high pressure system consisting of pipe lines with towns along the lines at intervals, the use of

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district governors with safety blow-offs makes it possible to omit the safety blow-offs on the individual services in the towns. This is on the assumption that the maximum pressure carried in the towns is not over 2 pounds. The advantage of low main installation cost and uniform service to consumers are then obtained without the necessity for maintaining the individual safety seals or assuming the slight additional hazard that is involved in carrying the full line pressure up to the consumers' premises. The requirements for peak load storage in the towns can be met by floating high pressure storage tanks on the pipe lines at points adjacent to the towns.

Pressure on Town Lines.—Companies report a range of pressure on town lines from holder pressure to 30 pounds. This is discussed under the item just preceding, headed "Reducing Governors," and the suggested practice is to carry a maximum of 2 pounds on town lines. Scattered villages and hamlets may be taken at full line pressure.

General Valve System.—There seems to be no particular connection with the number and location of the valves on the town lines and the pressure carried. In other words, some engineers are apparently of the opinion that frequent valves are required on town lines under 2 pounds pressure, while others are of the opinion that practically no valves are required under 20 or 25 pounds pressure.

In the older systems it was noted as a rule that valves were located at all intersections. It is apparent that valves are necessary to protect town lines where high pressures, say 30 pounds and upward are carried. The necessity for valves is to isolate certain sections of the town in order to make repairs. It is suggested that where the full line pressure is carried on the town lines, the same system of valves are used as on the pipe lines. That is, so that any mile of main in the town can be isolated. As in pipe lines, these valves should be covered with a substantial cast iron cover on a brick manhole.

Where the town is taken under moderate pressure, with a maximum of 2 pounds, as heretofore suggested as the best

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practice, it is not necessary to use valves except for the special locations prescribed for low pressure systems.

Tapping for Services.—The universal practice for making service connections to high pressure mains, whether town lines or pipe lines, is to use a saddle with a lead gasket. The service can then be run from a corporation cock on the high pressure or with the ordinary fittings on the 2 pound pressure.

Service Shut-offs.—It is suggested as the best practice that service shut-offs be installed outside the building on high pressure services regardless of whether the pressure is 2 pounds or 30 pounds. There are a number of installations using a maximum of 2 pounds pressure on town mains that do not use curb cocks or any shut-off cocks except the meter cock. While there does not seem to be any particular objection to this practice, the majority of engineers are still of the opinion that cocks outside the building should be employed on all services except the standard low pressure service.

The writer is of the opinion that outside shut-offs are not necessary where the main pressure does not exceed 2 pounds.

Special Safety Precautions.—As heretofore discussed, where towns are taken on district governors with a maximum pressure of 2 pounds on the town, the safety blow-off on the district governors will afford sufficient protection to the town mains and consumers and it is not necessary to equip the individual consumers with safety blow-offs. Where the towns are taken on full line pressure all consumers, and all consumers along the lines should be provided with safety seals with blow-offs of ample size and fully protected against stoppage.

Third Sub-Division.

General Policy.

Overhauling Ahead of Paving.—It is the universal practice to overhaul or make some special inspection of mains on streets which are to be paved. All the companies answering this question report that some such inspection is made. To what extent this should be carried can scarcely be standardized, but it is

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suggested that all mains to be covered with paving should be barred over and all services examined at the house and all drips be examined and repaired if necessary.

Minimum Size under Paving.—It is suggested that no cast iron mains smaller than 4 inches be allowed to remain below paving under any circumstances. If 2 inch or 3 inch cast iron mains are in streets, which are proposed to be paved, it would be the usual practice in large cities to replace with not less than 6 inch cast iron. Any 4 inch mains allowed to remain under paving should be examined for service taps and sleeves put on the mains if there are any holes larger than 1 inch tapped in the mains.

Main Inspection.—All the larger companies make some inspection of their mains, either in whole or in part and either continuously or periodically. The range is from the continuous daily line walk of all the mains in use, down to the periodical inspection of specific locations. One company reports the monthly inspection of all mains over bridges or other exposed locations. Another company periodically inspects mains where even slight leakages might cause damage, as around green houses.

It is not believed that it is possible to standardize this practice, but as an example the procedure of one works of moderate size is suggestive. This company inspects all hazardous places such as exposed mains and bridge crossings including the valve controls, every three months. Once a year a complete inspection of the street main system is made. This is done in the late fall and besides an inspection of the surface conditions over all mains, it includes an inspection of ditches over services of the past season. The intent of the inspection is to make sure that the conditions of the underground structures both new and old are in good condition as far as surface indications will show.

Special Inspection of High Pressure Mains.—It is suggested that a continuous patrol of high pressure pipe lines is advisable. The larger companies patrol their pipe lines daily and this practice is recommended.

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Where high pressure is carried into the towns the mains should receive the same attention as the pipe lines, that is, patrolled daily. Where the pressure is reduced to moderate pressure the same attention as to low pressure installations should be given, that is, a periodical inspection to be determined by the particular situation.

Test for Leaks.—The last two questions under general policy were not clearly understood and the returns were so few that the discussion is omitted. The tests for leakage by observing the drop in pressure in a long high pressure pipe line would not be satisfactory unless the leakage were so large that it would probably be discovered without the test.

Conclusion.

When the writer took up the work of digesting the data submitted by the various companies he was doubtful as to whether the information received would be of sufficient value and interest to make its preparation worth the effort.

It seemed likely that the practice in the larger companies would be so similar that there would be little to choose and that there would be few new ideas to bring out.

As the preparation proceeded this was found not to be the case and there seemed to be a wide variation in practice in many important items and these variations apparently rest on nothing except the opinions of the responsible engineers or superintendents or perhaps of their subordinate superintendents or foremen.

This paper could have been at best but a discussion of the data submitted. There was not sufficient time to take up by correspondence or otherwise any practice of unique interest submitted by any one of the various companies except in a very few instances. It is hoped that more will be brought out in the discussion.

In conclusion, therefore, the writer offers the opinion that, first, it is entirely possible to standardize street main practice; second, that such standards would be of value to all gas companies operating under American practice, regardless of size

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or geographical location; third, that if it is decided to continue the work it can only be done by a committee of the Institute, either working on this subject alone or on this combined with similar subjects.

Summary.

This summary is prepared for convenience in reference. It gives each item and the suggested best practice. Where no suggestion was made it is so stated.

Cast Iron Material.

Item	Suggested best practice	Page
Standards	American Gas Institute—1911	197
All Bell vs. Bell and Spigot Specials	All Bell to 12 inches	198
Reducers vs. Bushings	Bushings	198
Full Size vs. Reducing Fittings	Full Size	199
Type Drip Pots	Line Drips	199
Size Pumping Line	1¼ inch	199
Straight up vs. Off-set Pumping Lines	Off-set	199
Pumping Point Cover	Cast Iron Box (Standardized)	200
Use of Valves	Hazardous Location only	201
Valve Covers	Brick Man-hole	201
Location of Mains	No Suggestion	201
Depth of Mains	3 feet to 3 feet 6 inches	201
Grade of Mains	¼ inch in 12 feet	202
Blocking	None to 12 inches, Schedule 16 inches and over—Table No. 1	202
Protection against Corrosion	Clay Filling	203
Electrolysis	No Suggestion	203
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SUMMARY OF HEADINGS.

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- Mileage

MATERIAL

- Cast Iron
  - Pipe
  - Specials
  - Laying Data
  - Jointing Data
- Steel
  - Low Pressure Work
  - High Pressure Work

GENERAL POLICY

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Street Main Standards.

General Data.

Mileage—Low Pressure.

Size	Cast iron miles	Wrought iron or steel miles
2 in.		
3 in.		
4 in.		
6 in.		
8 in.		
10 in.		
12 in.		
14 in.		
16 in.		
20 in.		
24 in.		
30 in.		
36 in.		
42 in.		
48 in.		
60 in.		
Totals.....		

Percentage under paving .....

Material.

Cast Iron.

Pipe.

What standard followed? American Gas Light Association of 1898? American Gas Institute of 1911? American Water Works? ..

If none of the above, then what weight per foot?

Size	3 in.	4 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.
Weight								

Size	20 in.	24 in.	30 in.	36 in.	42 in.	48 in.	60 in.
Weight							

Depth of Bell:

Size	3 in.	4 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.
Depth								

Size	20 in.	24 in.	30 in.	36 in.	42 in.	48 in.	60 in.
Depth							

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Specials.

What standard followed? .....
In general are all bell tees and crosses used or bell and spigot? .....
Bushings or reducers? .....
Are openings at intersections left full size of line or are reducing fittings used? .....
Kind of drip pot—line or side? .....
Size of pumping line to drip pot. .....
Pumping lines run straight up from drip or off-set? .....
.....
Type of box or cover over pumping point?.....
Under what conditions are main valves used? .....
.....
Number in use? .....
Manholes or small covers over valves? .....
.....
Test pipes on valves? .....

Laying Data.

Location in roadway? .....
Standard depth to top of main? .....
What is the minimum grade you allow, and for what distance? .....
Do you lay on bare earth, or on blocking? .....
If on bare earth, any special preparation of earth? .....
.....
If blocking, give nature of wood and any schedule of blocking sizes followed for different size mains.....
Cast iron pipe ever protected against corrosion? .....
Against electrolysis? .....
Do you test joints before refilling? .....
If so, with air or gas? What gauge or soap-suds? .....
If with gauge, what pressure? .....
Do you use bag or stopper? .....

What methods are used to prevent stoppage by freezing in exposed mains, as on bridges? .....

If pipe is increased in size to form anti-freezers, in what proportion is diameter of pipe increased? .....

Is the maximum size hole allowed to be tapped in each size main fixed by schedule? .....

If so, give sizes.

Size of Main	3 in.	4 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.
Size of Tap								

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Size of Main 20 in. 24 in. 30 in. 36 in. 42 in. 48 in. 60 in.
Size of Tap .....
Is ditching ever done by contract? .....
Is ditching ever done by piece work? .....
Is ditching done by machine? .....
If any above methods of ditching used, give brief detail of advantages and disadvantages .....
How are ditches filled, as by scraping, tamping, flushing or machine tamping, under paving? .....
Where no paving exists or contemplated? .....

Jointing Data.

Lead Joints:

Size of Main 3 in. 4 in. 6 in. 8 in. 10 in. 12 in. 14 in. 16 in.
Depth of yarn.....
Depth of lead.....
Weight of lead.....
Size of Main 20 in. 24 in. 30 in. 36 in. 42 in. 48 in. 60 in.
Depth of yarn.....
Depth of lead.....
Weight of lead.....
Cast lead or lead wool? .....
Hand hammer or machine for caulking? .....
Character of yarn, tarred or untarred? .....

Cement Joints:

Size of Main 3 in. 4 in. 6 in. 8 in. 10 in. 12 in. 14 in. 16 in.
Depth of yarn.....
Depth of cement.....
Size of Main 20 in. 24 in. 30 in. 36 in. 42 in. 48 in. 60 in.
Depth of yarn.....
Depth of cement.....
Brand of cement? .....
Any other joining material? .....
If so, give details.....
If lead and cement both employed, what determines their respective use? .....
Any special precautions used in making cement joints in large mains over small mains? .....
Are clamps of Dresser type ever used over bell and spigot joints in low pressure or medium pressure, say up to 5 pounds?.....
.....
Why? .....

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STEEL.

Low Pressure Work.

Is steel pipe or wrought iron pipe specified? .....

Merchant or full weight? .....

What sizes are used in absolute preference to cast iron?.....

.....

What sizes in equal preference with cast iron?.....

Reasons for preferring? .....

Life expected? .....

Is coating used, and what coating? .....

Are any special precautions against corrosion taken, especially in bad soil, or where running along or across street railway tracks? .....

If so, give details.....

Are recessed couplings or ordinary couplings used? .....

.....

Are screw fittings used or fittings of the Dresser type?.....

.....

If screw fittings, black malleable, galvanized malleable or cast?....

.....

On repair work, are solid sleeves used or sleeves of the Dresser type, or are unions or other forms of conections ever used? .....

In using fittings of the Dresser type, is there any restriction where streets are paved, or likely to be paved, that is, do you fear failure of sleeve rubbers within the life of a pavement? .....

.....

What kind of pipe joint cement is used? .....

Depth laid? .....

Any provision for expansion? .....

Is pipe laid in ditch, or on top and then dropped?.....

.....

How finally blocked? .....

Method of testing? .....

Are any valves used, and if so, what is the general system? .....

.....

What kind of drips are used? .....

How is each size tapped or cut into for ordinary size services, say 1¼ inch? .....

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High Pressure Work.

General: Mileage.

Size	Cast iron miles	Wrought iron steel miles
2 in.		
3 in.		
4 in.		
6 in.		
8 in.		
10 in.		
12 in.		
14 in.		
16 in.		
20 in.		

Pipe lines, total miles? .....
Town mains, total miles? .....
Is steel or wrought iron pipe used? .....
Is this line pipe or what? .....
What kind of couplings? .....
Is it coated, and with what? .....
Kind of fittings used, as screwed malleable or screwed cast iron or Dresser type, etc.? .....
Kind of pipe joint cement used? .....
If cast iron pipe used, what maximum pressure allowed? .....
.....

Pipe Lines.

Expansion sleeves, how often? .....
Valves, how often? .....
Type of valve? .....
Any trouble from valve leakage, and how avoided? .....
.....
Depth laid? .....
Method of testing? .....
Are drips used? .....
What type? .....
Kind of covers? .....
Leaks fixed, how? .....
Pressure carried? .....
How are valves and drips marked so that they can be readily located in open country? .....

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Town Lines.

Is reducing governor used? .....

Pressure carried on town lines? .....

What is the general valve system used? .....

How is each size main tapped or cut into for services? .....

.....

Is there any special method for shutting off services outside of buildings, either separately or by sections of the town that is sectionizing the main system? .....

Are any special methods used for safeguarding installations? .....

.....

GENERAL POLICY.

Extent of overhauling or changing of structures prior to paving?....

.....

Minimum size of main allowed to remain in use where paving is planned? .....

Do you make a regular inspection of your mains? .....

If so, average time, in days, to cover system? .....

Number of men employed? .....

Annual cost? .....

Any special inspection of high pressure town mains? .....

.....

Any special inspection or patrol of high pressure pipe lines?.....

.....

Are any tests for leakage by meter made, either low pressure or high pressure? .....

Are any tests for leakage by pressure observations made in case of high pressure mains, that is, the fall in pressure over a period during which the main is shut off? .....

THE CHAIRMAN: Gentlemen, you have listened to the reading of two very interesting and instructive papers. They are now open for discussion, and I hope this discussion may be very snappy and spirited.

MR. J. D. SHATTUCK (Chester, Pa.): I differ from Mr. Rice in a good many points he has brought out. My experience has been that it is just as necessary to drain high pressure mains or grade them carefully as low pressure. Moisture

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gathers in all low points and stays there as long as the restricted area of the pipe is sufficient to carry the gas without much drop in pressure, but just as soon as the flow is great enough to cause the gas to pick up the water it is carried along into the next service causing trouble.

I am strongly against all cast iron fittings, cast iron valves and sleeve fittings. Sleeve fittings for expansion are unnecessary. It is possible to crowd pipe in a trench so that the amount of pipe is actually more than the lineal length of the trench. Enough pipe can be crowded into the trench to take up any possible contraction due to change in temperature under the ground.

I will not discuss Mr. Rice's paper further because the practice I am employing differs considerably from that set forth in this paper. My practice is more than that employed by the majority of natural gas and oil companies, which is laying pipe without expansion joints with cold rolled steel flanges with steel valves, bending the pipe cold to fit the curves and all necessary bends, even 90° bends on street corners with pipe as great as 12 inches in diameter. If the artificial gas man when he first went into high pressure had taken the trouble to observe the laying at some of these natural gas lines, he would have a better underground high pressure system in use.

Two years ago I began experimenting with welded pipe, and am now engaged in laying several lines by this method. In my first experiments it took me 40 minutes to weld a 4-inch joint. To-day we are welding 4-inch joints in 11 minutes and 2-inch joints in 2 minutes; using 40-foot plain end pipe more rapid progress can be made than with screw pipe and at less cost with a much tighter job. The joints are as strong as the pipe. We are using the acetylene oxygen torch.

First apparatus cost $1,000 and we discontinued our work for fear of the expense. Both acetylene and oxygen can now be purchased in tanks and the expense of the equipment is much less. The pipe we employ is plain and chamfered or slight bevel. The weld is made by use of a piece of Norway

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round iron. At first we turned the pipe in making the weld, but later found capillary attraction carried the molten metal without dropping underneath the pipe so that we are able to make the joints without getting underneath the pipe or turning it. By the use of a cutting torch it is possible to make all necessary fittings in the field, make cut-outs and repairs.

We have laid as high as 200 joints of 8-inch screw pipe in a day, using natural gas people's methods as against 800 feet with the old fashioned chain tongs. I would particularly emphasize the necessity of protecting the sleeves, and valves by large ventilated manholes so that there is no possibility of leaking gas spreading under pavement or frozen ground.

The practice that I have given you may run up the cost per foot of main slightly, but when you practically eliminate the leakage, it is well worth while. The valves I am using are the most expensive item as they are heavy high pressure steel flanged valves with cold rolled flanges. This is necessary to stand any contraction strain that might come at a valve. All our valves are tapped underneath the gate and have a pipe connection leading to the surface through which the sediment is blown out before seating the valve. We have felt that it was the sediment underneath the valve seat that caused our valves to leak, and not as in Mr. Jones' case the destroying of the seats by sediment flowing through.

Mr. Jones (San Francisco): I hesitate to take the time of the convention on account of the isolated district from which I come, but the subject of these two papers is very close to my heart. The first point, covered by Mr. Rice's paper, the coating of wrought iron and steel mains, I have run the the gamut of all the coatings, lead, tar and everything else, and I find the trouble with the coatings as a whole is the method of applying them. I discovered from an English concern, a method which we are now using on the coast, and I find we have the best material for coating pipe right in our own works, whether it be coal or water gas. On the coast we use oil tar; and it pays every company, no matter how small it is,

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to own a little tar still for distilling its own tar. We distill the tar, first taking out the water. Then we distill it to get a pitch for the final coating, using the benzole for a thinner for making paint. First we apply to the clean pipe a coat of tar paint, applied cold with a brush. That is allowed to dry. Then the pipe is swabbed over with a coat of hot pitch as thick as can be applied, one-quarter of an inch, if you please; the thicker the better. The theory is this: Hot pitch will not adhere to cold metal, and hot pitch is the best coating for wrought iron or steel. If you coat the clean metal with a coat of tar paint applied cold with a brush, and then apply the hot coating above the cold coat it amalgamates, it immediately forms a combination; the cold coat fixes itself to the metal and the hot coat melts the cold coat and makes a permanent coating. It is also a partial protection against electrolysis. The coating is extremely inexpensive. We do it ourselves.

In regard to jointing mains, we have been welding altogether on the Pacific Coast for some time. We use the oxyacetylene torch, and we use no gasket joints, because we have had so much trouble with the gasket, both rubber and asbestos, and even lead wire where climate permits us to use it. We make no allowance for expansion. I have never found the necessity for it. We use the oxyacetylene torch for pipe. We use no cast iron fittings. We make our fittings on the job. We make Y fittings for the convenience of gas getting from one pipe to another, and we make tees, crosses, drips and everything else on the job, and they are very inexpensive. The only fittings that we use are a few flanges. We make use of the O. D. & I. D. pipe for connecting valves, etc., because fortunately they will slip over each other and we weld the two together. If we want to put a service into a steel main we take the torch and cut a hole in it and build up a base of Norway iron around the hole, tap it out and screw a cock into it, without any trouble whatever. We find it pays a company to have the best portable welding outfit they can possibly purchase, on an automo-

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bile permanently used for that purpose, so you can get quickly to the work. We buy our acetylene gas in large cylinders because it is more convenient to transport it under pressure than it is to make it on the spot and lay long lengths of small pipe to the joints, and we have the thing down to a small compass and great economy, and by the way, the cost of oxygen and acetylene is greatly reduced. On an 8-inch O. D. line laid recently about 6 or 7 miles in length, we used 16 feet of oxygen, which cost 2½ cents per foot, making 40 cents for oxygen, 9 feet of acetylene at 2 cents, amounting to 18 cents for acetylene, which together with the labor of welding and iron used and the fitter at $3.75 for 8 hours, a helper for $2.75 for 8 hours, and other items, making the total of 81⅗ cents for each joint, compared with $2.00 for other forms of joints.

In regard to laying pipe deep or shallow, the Almighty has arranged so that the frost comes out from the bottom of the ground in the spring, and it is much better to have pipes frozen up all the time rather than to have the reaction going on. When we slush around during the spring thaw or the mid-winter thaw in a little bit of surface mud, that does not apply to the frost below. When the frost permanently leaves the ground it comes out from the bottom, due to the interior heat of the earth in combination with the heat of the sun on the outside, so I think when we consider depth sufficient to protect pipes against heavy teaming traffic and all that sort of thing, shallow mains laid in frost are better than mains that are laid between wind and water, frozen part of the time and thawed out the rest of the time.

Mr. C. W. Andrews (Duluth): I think we ought all to be very much interested in these papers. In regard to the coating Mr. Jones speaks about, we find that it is just about as good as anything you can buy, and is at the same time very cheap.

I do not see any reason why the extra coat of pitch will not assist very materially in preserving the pipe for an indefinite time.

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In regard to the use of steel or wrought iron pipe, the fact that 80 per cent. of the pipe used is steel would indicate that there is not a great deal of difference between the two materials. Asbestos gaskets have been spoken of in both papers as being practicable. It seems to me in distributing artificial gas we should use asbestos gaskets as far as possible, on account of the action of the hydrocarbons in the gas on rubber.

In regard to taking out moisture in the gas, there seems to be no doubt that more attention could profitably be paid to this subject. In our plant we find every spring that the frost which accumulates in the mains near the works is carried forward on account of the heating of the ground from the flow of warmer gas into the small mains which run in outlying districts where the ground is still frozen. In this way practically all our trouble from frost is in April and May, rather than during the winter. This we hope to obviate by taking more of the moisture out of the gas before it is turned into the system.

MR. G. T. MACBETH (Mt. Vernon, N. Y.): On Mr. Rice's paper, under "Choice of Pipes," there is a paragraph reading "In high-pressure system (referring to wrought iron pipe and steel pipe) it is the only suitable pipe for pressure above 5 pounds. In low-pressure system use will be found for it." I do not agree entirely with the statement that wrought iron pipe is the only pipe suitable for high-pressure system work. We intend to carry as high as 10 pounds on 16-inch cast iron mains with lead wool joints. I do agree with him if the pipes are 6 inches and smaller in size. I also heartily agree with the last paragraph that wrought iron pipes can be very satisfactorily, conveniently and economically used for low-pressure mains. If for instance you have a street with a large per cent. rock and are required or desire to lay gas mains in it and the sewer is not already laid in the street, I think it is foolish to put cast iron pipe in it, because you are going to have some one on the job all the time that the sewer is being

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laid. If wrought iron pipe is put in you do not have to watch it at all during the time the sewer is being installed but can go back and relay your wrought iron pipe or substitute cast iron. By that time you may want to change the size of the pipe, which can be done at the same time.

THE CHAIRMAN: I am sure Mr. von Maur has some excellent thoughts for us on these two papers, and I am going to ask if he will not give them to us at this time.

MR. J. D. VON MAUR (St. Louis): I do not know, Mr. Chairman, that I have anything to add to what has already been said, and certainly nothing to add to what has already been so admirably covered by Mr. Shattuck and Mr. Jones.

There is one detail in connection with the American Gas Institute standard of drips to which I would like to draw your attention. I see no need of the open top drip, which is provided with the large bell and plug. Neither do I see the necessity of a line drip with a 12-inch top plug. Our drips are made with a very light bell which is closed by a light 6-inch plug. I have been advised that it is difficult, from the manufacturers standpoint, to manufacture such drips, but we have not had the least difficulty in having them made at our local foundries in St. Louis, or, for that matter, by some of the Eastern foundries.

Then I am gradually coming to favor side drips. I believe that a good rule to govern the installation of a distribution system will be to so lay out the underground so as to require a minimum of wrought iron or steel pipe, and to do nothing repugnant to common sense. This means that mains should be laid near the curb, and side drip pots used, connected to the main by means of cast iron pipe. There are more advantages in the use of the side drip pot than at first seem apparent.

The question of the use of cement for joint making purposes seems to be still unsettled. All my remarks are, of course, based on St. Louis practice.

The best proof that the kind of cement used is one of the

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most important factors to be considered, is best shown by some of the results which we have obtained with Dyckerhoff cement. We have, in St. Louis, a number of mains which were laid many years ago, using this brand of cement, and these mains have remained in most excellent condition, many of them under very trying circumstances. We have a 16-inch main which is laid so that the bottom of the street railway ties is only 8 inches above the main, and yet we have never had a leak on this main in 15 years, and we have uncovered a number of joints and found that they test as tight to-day as the day they were put in.

As I said before, we have not found any leaks, caused by cement joints, in the last 12 months, and we have not had any before, except where other brands of cement had been used.

I am not sufficiently versed in the chemistry of cement manufacture to explain just what quality in the foreign cement makes it so well adapted for joint making purposes, but I rather imagine that it is due to the fact that the cement from abroad is bound to be thoroughly seasoned before we use it. We find it necessary to place our order some 6 months in advance of our actual needs. I tried to keep some domestic cement in stock for the purpose of ageing it, but some how or other the proposition did not work out and the difference in cost does not seem to warrant any more experimenting with the cement proposition.

As I said before, we lay the greatest stress on the necessity of having a good foundation under the pipes. If the blocks under a 24-inch main, for instance, are so laid as to bring the top of the block flush with the bottom of the trench, then we will have, to begin with, approximately one-half ton of pipe resting on each block, less the amount supported by the undisturbed bottom of the trench. Now if the blocks settle an infinitesimal amount, such settlement brings additional bearing from the bottom of the trench, so that even if in the beginning the pipe does not have a theoretically perfect bearing

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under the entire bottom of the pipe, even the slightest settlement assists in approaching this desired condition.

MR. H. W. TERRY, JR. (Ossining, N. Y.): A little over a year ago we installed a high pressure system and tested it with air at 70 pounds pressure per square inch, going over all the valves with soap and water and found them tight. When we put 20 pounds pressure per square inch of gas in the line we found that we had a number of leaks in the stuffing boxes of the valves. I would like to ask if any body has had that experience,—valve stuffing boxes tight at 70 pounds air pressure and leaking with 20 pounds gas pressure?

MR. J. D. VON MAUR (St. Louis): We have taken 12-inch pipes where the joints were made in cement and lowered an entire block without causing a single joint to leak.

MR. E. C. JONES (SAN FRANCISCO): I omitted one point in Mr. Vincent's paper, which might cover our friend's question, that is the putting in 2 valves in high pressure lines, one to take the place of the other in case of accident. I found out after long experience with high pressure distribution that all high pressure valves ordinarily placed in the line leak, and as long as we don't know they leak it don't bother us at all, but when we go to a valve and find it is no longer a valve it is time to find out why. If you place valves in high pressure lines as you are laying it, the valves of course having comparatively soft seats and plugs, and there is considerable steel scale in the new pipe, the moment you open the valve the steel scale will cut the valve seat. You have perfect confidence in something that is absolutely useless. If I put in a 6-inch valve I put in an inch and a quarter or 2-inch by-pass with a valve around it, that I can afford to waste in order to preserve the larger valve, and when it becomes necessary to open the valve I open the by-pass valve first and equalize the pressure on both sides of the valve, and then open the main valve, thus protecting the main valve from damage. Do not for a moment think that valves are tight and will not leak because you have valves in your high pressure system which are not valves at all, and some

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day you will have an experience such as I have had recently with strike conditions when all your men are out on strike, and a tight valve is a mighty useful thing. All high pressure valves should be by-passed.

MR. J. D. SHATTUCK (Chester, Pa.): We used to have a good deal of trouble with leaking stuffing boxes, but since we have employed the heavy type valve we have overcome this.

MR. H. S. BATTIN (Philadelphia): I agree with Mr. Shattuck that it is very important to lay all high pressure gas mains to grade. I would like to inquire a little more about the combination lead and cement joints for cast iron bell and spigot mains. I understand that a 16-inch cast iron high pressure main was laid between Paterson and Passaic about 4 years ago with joints made of a combination of cement and lead. If any of the Public Service people are here I would like to have them state whether the joints of this main have held up. I understand that gas is pumped through this main at a pressure of about 5 pounds per square inch.

MR. THEODORE BUNKER (Paterson): In answer to Mr. Batton's inquiry, would say that we laid a 16-inch pumping main between Paterson and Passaic about 3 years ago, making every effort to have the main well laid and the joints tight. The main was tested under 10 pounds pressure and the joints made tight before they were covered in. We made all cement joints. Subsequently in the course of a year we found this main to be leaking badly. We cut out a proportion of each cement joint that we found leaking and poured a lead joint on top of it. This combination joint was an improvement over the cement joint in that we found only seeping leaks instead of badly leaking joints.

It has been our recent practice to make combination joints in the first instance. We believe that it is best to pour the lead joint while the cement is still green for the reason that the caulking of a lead joint against a cement joint that has been allowed to set up firmly would we believe destroy the tightness of the cement joint.

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We have had difficulty in understanding why cement joints made under apparently the same conditions vary in the results obtained. We had a series of fifty (50) joints made by the same caulkers under exactly the same conditions. In one case every joint leaked, and in the other case 90 per cent. were tight. The difficulty of being insured of a good cement joint at the first effort led us to adopt the combination joint where a small leak can be corrected without cutting out the entire joint.

I made a test of a 12-inch main designed for low pressure, but which might later be used for a higher pressure, say five (5) pounds. It was thought best to test the main under ten (10) pounds to insure tightness. As the pressure was raised from one-half (1/2) to five (5) pounds, every joint was made to leak. Some were tight at one-half pound, still others at a pound, but by the time five (5) pounds had been reached, every joint was leaking. This raises the question as to whether it is wise to put such a pressure on a practically green cement joint.

If I have not exhausted my time, I would like to say a word about coating mixtures. It seems to me we are going at it in an unscientific way. We acknowledge in the first place that certain soils do not require coating of wrought iron or steel pipe, and I suppose in most places 90 per cent. of the soil is of good character. I do not believe any pitch or tar compound will protect pipe from acid soil. I think the only way to protect a service pipe is to coat it thoroughly with cement.

As far as electrolysis is concerned, I don't believe you can cover a service pipe with pitch, haul it to the job, screw it up and do all the work necessary without so damaging the coating that if there is an electric current coming along that line it will find some place to escape and eat out your service pipe. I am arguing for a cement coating that is put on at the time the service is laid, when you can see it is all thoroughly coated, even including the fittings.

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THE CHAIRMAN: I am sure all present would like to hear from Mr. Forstall on these two very interesting papers.

MR. WALTON FORSTALL (Philadelphia): I think that most of us are apt to be somewhat skeptical as to the value of lists of questions sent broadcast, and undoubtedly a number of us who received Mr. Vincent's questions were dubious of any good results to come from answering them. Now, however, that we have read this paper, it is safe to say that there are few who have not found in it subject for thought and have not had occasion to review their own practice along the various points brought up by the author. Undoubtedly the paper has a great educational value, for even if as a result of reading it, no one changes their practice, such decision should be only because after due consideration, the present practice is considered best for the local conditions.

It is encouraging to note the large percentage who are adopting the 1911 Institute standards. One wonders what reason could be given by the companies not following the standard for their non-acceptance of it. Every gas engineer should not only adopt the standard, but should urge the foundries supplying him with the pipe and special castings to change over all of their patterns to the new standard as fast as possible.

I think that most small gas works would profit by following the suggestion of keeping in stock all bell branches only. It happens that in Philadelphia two-thirds of our streets, known as minor streets, are undetermined in location until the building of houses. Therefore, we have many occasions when it is necessary for us to insert a branch into an existing line. For this reason, in our case, it pays us to keep a stock of all bell as well as bell and spigot branches. In the same way carrying reducers in regular stock, using bushings for all ordinary cases of size reduction, is to be recommended.

In reference to the size of the drip pot pumping line of standpipe, the author states that he uses 1¼-inch, as this pipe, as compared with 1 inch used by a majority of the companies,

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has thicker walls to resist corrosion, at but little extra cost. Based on the following table, it would seem as if in most situations the use of 1-inch extra heavy would be preferable to 1¼-inch as securing the greatest thickness for the least cost per foot:

	Thickness of metal		Price per foot	
Size	Standard	Extra heavy	Standard	Extra heavy
1 inch	0.133 inch	0.182 inch	0.035	$0.0462
1¼ inch ..	0.140 "	0.194 "	0.0453	0.063

I use the expresion "most situations" because in large cities the time is probably coming when the use of power pumping for drip pots will be quite common, and, therefore, the pumping pipes of the drips on the larger mains should be not less than 1¼ inches, and in some cases 1½ inches and 2 inches.

I think most of us ought to hear something which I want put on the record. We are using in Philadelphia a 7,000-pound electric wagon with a 600-gallon tank for pumping all of our drips, and we have made quite a little economy. We have an electric pump on that drip, and if you run across 3,000 or 4,000 gallons in a drip, it is very nice to pump it by electric power and not hand work.

Personally, I have always been opposed to offset pumping pipes. If the drips require frequent pumping and collect much condensation, I think the extra friction due to the offset, would be objectionable. If the drips do not require much pumping, the disadvantage of an objectionable location necessitated by a straight pumping pipe is minimized.

The author is of the opinion that "if it would be practicable to lay gas mains at such a depth, that under no conditions would they be reached by frost, it would be advantageous from the standpoint of safety to the mains." Prior to January, 1912, I would have agreed with this statement. Since then, however, as a result of the investigations I made on the effect of the cold weather of January and February, 1912, on the distribution systems in a number of our northern cities, I have come to the conclusion that the effect of frost on well made and well laid pipe, of ordinary size, would never warrant

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the extra cost of, say, 1-foot increase in depth. I say of ordinary size because I am a little uncertain as to the effect of temperature extremes on cement joints for pipe 16 inches and larger, although in Philadelphia we have not been able to trace the failure of large cement joints to extremely cold weather. The experience of 1912 seems to show conclusively that mains are not harmfully affected by frost depth, unless the frost line stays for a long time at just about the top of the main, and this condition is combined, for pipe 4 inches and smaller in size, with rather a poor foundation.

I would like to say right here we expected a good deal of trouble when frost went out of the ground in 1912, but we did not get it. Our breaks came when the frost had just reached the top of the main and apparently pressed the mains down on insecure foundation and broke them.

Then we have all the elements necessary for many broken mains. On the other hand, if the frost depth, quickly goes below the pipe, as will be true in most of our cities North of Chicago with pipe cover of 3 feet, the pipe at this depth is apparently as safe as it would be at a depth of 4 feet. I, therefore, see no reason for a greater standard cover than 3 feet, this cover having proved itself sufficient, with the present weight of pipe, to protect from traffic strains and affording sufficient service depth.

With regard to the question of blocking, the speaker would refer you to his paper read before the present meeting, in which he gives reasons for advocating the use of blocking.

No one is justified in using bags where stoppers will do as well, for the latter are safer and more economical than bags, which, as stated by the author, are only required for pipe out of round either through poor casting or the presence of foreign material.

Regarding the maximum tap hole allowable in any size main, in Philadelphia we allow 1½ inches in 6 inches, 2 inches in 8 inches, 2½ inches in 12 inches, 3 inches in 16 inches, 4 inches in 20 inches and in 24 inches. These, you will note, are

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a size larger than given by the author in his table. We have not had any trouble from mains breaking at these tap holes. I agree thoroughly with the author in his objection to 1¼-inch hole in a 4-inch main. In his table, he shows 4 inches as the maximum tap hole allowable for sizes up to 48 inches. We would not tap a larger hole than 4 inches in any main simply because we would not use for connection to a cast iron main, steel pipe in any size larger than 4 inches. We would, however, not hesitate when putting on hat flanges, to make openings varying from 8 inches in a 24-inch to 12 inches in a 48-inch main.

The author's theory for the failure in cement joints in large pipe, is a very interesting one. I hope to make some temperature observations this coming winter and next summer to ascertain temperature differences between the top and bottom of a large main on very cold and on very hot days. We have had a number of failures of large cement joints in Philadelphia, but our experience does not seem to us to agree with the author's theory that the trouble is due to temperature differences between top and bottom.

With regard to the combined lead and cement joint, it is not clear to me how it can be proved that the tightness of the joint is due to the combination of the two materials. From what we have heard from New York about lead wool joints, it would seem that the tightness might be ascribed to the lead wool alone, and from what I saw on one occasion of the making of these combined joints, I am inclined to believe that the lack of temperature precautions in connection with the cement portion of the joint would be apt to cause such a separation of cement from iron as to make the cement joint of little use as an anchor.

I believe that this joint question is one of very great importance, and that the Technical Committee during the coming year should, through a sub-committee, have the subject thoroughly studied. With the right men making the proper experiments, much might be learned for the benefit of the whole business.

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I have a communication from Mr. Ganz, which can be put in the record without being read.

PROF. ALBERT F. GANZ (Hoboken, N. J.): I would like to add a few words in regard to the relative corrosion of wrought iron, steel and cast iron pipe caused by electrolysis from stray electric currents, and in regard to the effectiveness of protective coatings for iron pipes.

Stray electric current on a pipe line lying in ground produce corrosion of the iron by electrolysis at every point where such current leaves the iron to flow to surrounding soil. The mass of iron corroded by electrolysis by a given amount of electric current in a given time is the same for wrought iron, steel, cast iron and in fact for all kinds of iron, and is equal to 20 pounds of iron for every ampere-year. Current generally leaves iron pipes for soil from localized areas resulting in localized corrosion of the metal. When cast iron is corroded by electrolysis, the oxides of iron resulting from electrolysis usually remain in place forming a material having the consistency of hard graphite and leaving the outward appearance of the pipe unchanged. This graphite material together with the surrounding soil frequently prevents noticeable leakage of gas or water, even after the pipe has been entirely corroded through the metal. In such cases a physical examination with a test hammer or a knife is required to establish definitely whether or not it has been damaged by electrolysis, and the graphitic residue can usually be dug out with a knife exposing pits in the pipe. On the other hand when stray electric current leaves a wrought-iron or steel pipe or pipes of similar material for ground, the oxides of iron resulting from electrolysis are diffused through the soil, resulting in pits which eventually go entirely through the wall of the pipe and produce leakage. While as already stated there is practically no difference in the rate of corrosion by electrolysis between cast iron, wrought iron and steel, the electrical resistivity of cast iron is however about 10 times as great as that of wrought iron or steel, and the usual lead joints in cast iron pipes have a resistance which

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is many times greater than the screw-coupling joints usual with wrought iron and steel pipes. For these reasons a given voltage drop through ground will cause a much smaller current to flow on a cast iron pipe line with lead joints than on a wrought iron or steel pipe line with screw-coupling joints, thus practically making cast iron pipe lines much less subject to electrolysis than wrought iron or steel pipe lines with screw-coupling joints. These facts are borne out by experience, for it is often found that where wrought iron or steel pipe lines with screw-coupling joints and cast iron pipe lines with lead joints lie in ground in close proximity and are subjected to exactly the same conditions, the current flowing on the wrought iron or steel pipe is many times greater than the current flowing on the cast iron pipe.

In regard to protective coatings, no paint or similar coating will permanently protect an iron pipe against electrolysis in soil. The first difficulty is to apply the paint so as to form an absolutely perfect coating, and then to prevent mechnical damage to the coating. Where imperfections exist or develop aggravated trouble may result. Experience further shows than even where coatings are apparently intact, electrolytic action is not always prevented, and in fact very serious electrolysis pittings have been found under apparently good coatings. It has been found that in most cases the coatings applied have either been completely destroyed by the effects of the wet soil and the electric currents, or defects in the coatings have developed causing concentrated corrosion at such defective spots. The effect of stray current upon paints and similar coatings which are not entirely moisture proof is to gradually destroy the coating. This destruction goes on where current flows from soil to the pipe, as well as where it flows from the pipe to the soil. Pipes in positive districts covered with imperfect insulating coatings are in greater danger from electrolysis than bare pipes. Coating pipes in negative districts with insulating coverings does some good in reducing the amount of stray current which reaches the pipes. The only

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kind of insulating covering which appears to afford protection against electrolysis is a heavy layer of a material like coal tar pitch or asphaltum, preferably 1 or 2 inches in thickness, of such a grade that it is not brittle and so will not crack, but yet is hard enough to remain in place.

Cast iron, wrought iron and steel pipe lines laid in ground where there are large stray currents have been protected by the use of insulating joints. A pipe line laid entirely with insulating joints has a comparatively high resistance and cannot carry stray electric currents. It is sometimes possible to use comparatively few insulating joints to break up the electrical continuity of a pipe line, and protect the line from electrolysis, but such joints must be installed only after careful tests have shown that the current is not likely to shunt through ground around them and so do more harm than good. This depends largely upon the potential gradient through ground and upon the electrical resistivity of the ground.

Following is discussion by Mr. von Maur on Mr. Vincent's paper on Street Main Standards:

Mr. Vincent has certainly written a most excellent paper, and has brought together, in a systematic manner, a great deal of data which will undoubtedly add great value to the literature on distribution topics.

It occurred to me as I read the various papers by Messrs. Vincent, Rice, Forstall, Simpson and Gould that they might well be discussed together, as the subjects touched upon all bear a very close relation to each other. It is well nigh impossible to discuss each one separately without some repetition.

I will endeavor to discuss Mr. Vincent's paper in the order in which he has arranged the topics.

Bell and Spigot Fittings.—While it is an unquestionable advantage to have all bell fittings, it is also an advantage to have a reasonable number of fittings one spigot, for cutting out purposes. While it is true that with the all bell fittings this takes but one extra joint, it must be remembered that this frequently means the cutting up of asphalt, and in many

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instances a great deal of excavation would have to be done which could be avoided if the connection could be made by using simply the fitting and sleeve.

Drip Pots.—In any city having a corrosive soil, or where there is electrolysis, the following rule for good distribution I believe to be applicable, namely, "So lay out the distribution system as to use the minimum amount of wrought iron or steel pipe, and do nothing which is repugnant to common sense." This rule will apply to many conditions, as for instance once when I, mentioned in connection with the discussion of Mr. Simpson's paper, namely that the gas main should be laid close to the curb, and when the street becomes congested a second main should be laid close to the opposite curb. This results in the minimum amount of service pipe, applying this to drip pots would mean that a tee should be placed in the line, and the drip placed inside of the curb. Under this condition there will be very little maintenance, all danger of broken stand pipes will be avoided, the riser of the drip can be rodded, and the capacity of the drip can be increased without cutting into the street, and a standard line drip can be used to take the place in many cases of larger size drips. For instance if a 12-inch line is being laid, necessitating a drip draining a very short length of main, a smaller size drip could be placed inside the curb. I appreciate, of course, that the line drip in all sizes will have to be maintained for use in places where the side drip will not make a practical and economical construction.

Offset Pumping Pipes.—I do not approve of running the pumping pipe up straight from the drip pot where the latter is set in the street. This was the practice in Philadelphia many years ago, and I naturally followed the same practice in St. Louis, but it gave us so much trouble that we not only abandoned the practice, but changed the location of the pumping pipe in all cases where it had previously been installed in the street.

Valve Covers.—I believe it is a mistake to build a manhole

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around a valve from the bottom of the valve to the surface of the street. We fill in around our valves to a point close below the stuffing box, at which point we place our concrete, allowing only the stuffing box to be seen from the manhole cover. It has been my experience when any work is to be done on a large valve that the manhole is practically destroyed in any event, so that it is better to adopt the more economical construction in the first place.

Location of Gas Mains.—I have already stated my views on this subject in discussing Mr. Simpson's paper. It must be evident that if the location of 4 feet from the curb is adopted that electric conduits, water pipes etc., which are subsequently laid may be so located as to seriously interfere with the installation of gas services.

Blocking.—This is also a subject on which I have already expressed my views. Our theory is that blocking should be placed under the pipe, near the bell and spigot, the top of each block to be flush with the bottom of the trench, and that the greatest care should be taken to leave the bottom of the trench undisturbed. If a 24-inch pipe, for instance, is laid on such blocks there would be probably one-half ton supported by each block. The undisturbed earth would in the beginning support part of this weight. Should the blocks settle the merest trifle, or should they rot a small amount, allowing the pipe to settle the least bit, then immediately more pressure is transferred to the earth, so that even though the bottom of the trench might not be theoretically a perfect plane, every additional trifle of settlement results in bringing an additional undisturbed ground foundation to support it.

Testing Joints.—There is no question in my mind but that every piece of construction should be tested. It is never safe to assume that a joint is tight, without test. I have seen joints made in the most perfect manner, even with lead wool, where a leak was discovered on test, the air finding its way through a porous bell.

Ditching and Filling.—Suburban work can certainly be

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done most economically with a trenching machine, provided there is a sufficient amount of work to justify the purchase of one. If no machine is available, and the work is sufficiently large in volume, it will be found interesting to note the results obtained by digging the trench on the piece-work system. It is simply remarkable the amount of trench that men can excavate when they are digging on a piece work plan. Of course neither of these methods is available in large cities.

Brand of Cement.—Mr. Vincent states that he has no report of any company using German Portland cement. I wish to say that in St. Louis we use Dyckerhoff cement exclusively, and to it we attribute a great deal of our success with cement joints. In 12 months we have not had a single leaking cement joint. Of course there may be leaking joints of which we have no knowledge, but certainly none has come to our attention.

We have one line of 30-inch pipe made with cement joints which has never given us any trouble, and we have examined a number of 24-inch high pressure cement joints which have been equally satisfactory. The only leaking cement joints which we have had were those where Dyckerhoff cement was not used.

Referring to Mr. Vincent's suggestion, at the bottom of page 209, regarding a combination joint, would say that it would seem to me the very best joint could be obtained by first caulking in the joint say one strand of yarn, then one and a half inches of lead wool, following which would come the Dyckerhoff cement joint. This ought to combine all of the advantages of both materials, without waiting for the cement to set, as would be the case if cement were first used, and then followed with lead wool.

I would like to ask Mr. Vincent whether his estimated cost of the special deep bell at top of page 211 includes the extra cost of the bell itself?

Much of what follows in Mr. Vincent's paper represents common practice, and a great deal of it has been covered by

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other papers. There is just one thing that should be borne in mind when considering data obtained from answers received from a set of questions sent out to a great number of companies. The mere fact that a large majority of concerns are doing work in some particular way does not in itself prove that that way is the correct one. In order to get the "real meat" of the whole matter it will be necessary to have in addition to the answers, the results obtained in each case. It must be remembered that in the final analysis the best system or method of doing work is that which under a given set of conditions produces the best results.

The following is discussion of paper on "Street Main Standards" by Mr. H. S. Battin:

Mr. Vincent has made a very thorough analysis of the answers from the various companies to the questions sent out covering the street main standards. I believe that Mr. Vincent's conclusions generally agree with what is considered good practice in street main work. There are, however, a few points on which I do not exactly agree with him and which I will take up in detail.

Full Size or Reducing Fittings.—Mr. Vincent comes to the conclusion that full sized fittings should be used at intersections of all cast iron main up to 12 inches in diameter. As a general rule, trunk main lay-outs are developed for each city, and this lay-out can be made to cover the development of the distribution system for a number of years. Of course, occasionally this lay-out must be changed in order to take care of unexpected developments in the business in certain sections of the city, but, as a general proposition, the trunk main lay-out can be made to cover the general growth of the distribution system. This being the case, I do not believe it is necessary in running say a 12-inch line, to put in full size specials at all intersections, as in a number of cases 4-inch, 6-inch or 8-inch openings would be sufficient for an indefinite period.

Drip Pumping Lines.—I believe it is good practice to extend the pumping pipe straight up from the drip pot on streets

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that are paved or to be paved in the near future, but on paved streets I would recommend the drip pumping line be extended to a point just inside of the curb line. In Northern and Western cities, where snow and ice cover the ground for a considerable period during the winter, I would extend the drip pumping line to a point just inside of the curb, as otherwise it would be almost impossible to get at the drips to pump them.

Cement Joints.—I do not believe it is any advantage to have lead joints at fittings, or in the middle of blocks. I find that main laid with all cement joints, both in the pipe and fittings, remain just as tight as ones laid with an occasional lead joint; in fact, I believe the lead joints are more apt to leak when put in in the above cases, than would otherwise be the case.

I am inclined to agree with Mr. Vincent in the conclusion that cement joints on cast iron mains 16 inches and over are very apt to leak sooner or later. It would no doubt be an improvement if the bells on the larger pipe were made deeper, where cement joints are made.

I understand that some companies have made a combination lead and cement joint on mains 16 inches and larger, and that these joints have remained tight under pressure up to at least 5 pounds per square inch. It is recommended in cases of combination cement and lead joints, however, that the bell should be made at least 5 inches deep for 12-inch and 16-inch main, 6 inches for 20-inch, and 7 inches for 24, 30 and 36-inch.

I am not entirely satisfied in my own mind that this combination cement and lead joint will remain tight for any extended period, and simply mention the matter so that it can be considered with the general subject of main laying.

Clamps.—I believe it is doubtful whether leak clamps on cast iron mains carrying up to say 5 or 10 pounds pressure are reliable, especially clamps using a rubber gasket. Clamps using the asbestos gasket have not been in use long enough to test out their reliability, although I believe they are the most

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reliable clamp on the market to-day for use on mains carrying artificial gas.

Steel Material for Street Mains—Expansion.—I note that Mr. Vincent has come to the conclusion that it is not necessary to make any provision for expansion in wrought iron or steel mains. My experience in laying high pressure steel mains seems to indicate that it is necessary to provide some kind of expansion in lines of 8 inches and over. In the smaller sizes I believe it is possible to lay the main in such a manner that expansion joints are not necessary. I know of a double line of 8-inch main laid about 2 feet 6 inches deep. The pipe was the regular full weight line pipe with taper threads and recessed couplings that pulled apart the first winter it was laid in at least half a dozen different places in a length of 20 miles. The same thing happened to two lines of 10-inch pipe laid with the same material and couplings. Another stretch of two lines of 10-inch main laid through a city street where the main had to be laid parallel with the curb and in a straight line, had expansion joints installed every 1,500 feet. These lines have never pulled apart.

Valves.—In a high pressure line I believe it is advisable to locate valves about one mile apart and on each side of railroad and river crossings.

Inspection of High Pressure Mains.—I do not believe it is necessary to patrol high pressure lines daily in towns unless the pressure is carried over 30 pounds to the square inch. I would recommend, however, that periodical inspection of high pressure mains be made in order to make sure that there are no leaky joints in the mains or services.

I strongly recommend the installing of curb service cocks on all high pressure services. These cocks should have full gasway.

With the few exceptions noted above, I endorse Mr. Vincent's conclusions covering the standard to be recommended in main laying practice.

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MR. J. A. GOULD (Boston): We happen to have duplicate 30-inch mains parallel to each other, one laid with cement joints, the other with lead joints. The main with lead joints was laid about 25 years ago, and the main with cement joints about 10 years previous. In looking over the leak records for the past 20 years I find in the first street that there were three and one-third times as many leaks found in the lead joints as there were in the cement joints. In the next street there were 10 times as many leaking lead joints as there were leaking cement joints. We also have a 30-inch main laid 16 years ago where two-thirds of the joints were of cement and one-third were lead, that is every third joint was lead. Eight leaks developed in the lead joints to every one in the cement joints, and as there were twice as many cement joints as lead joints, the ratio was practically 16 to 1 in favor of cement. This main was 2 miles long.

MR. WM. A. TOBIAS (Schenectady): I would like to ask on what size mains it is advisable or rather imperative to begin the use of stoppers in conjunction with the use of bags. I have been using stoppers in conjunction with bags on 8-inch mains and larger, and use bags only on everything below 8-inch. In reference to the cement joints, there has been so much said about it that it is almost impossible for me to add anything, but, unfortunately I have been located in a city the past 5 years where previous to my coming there the distribution work was generally done by contract and mostly lead joints. I have dug up not more than 4 cement joints that have leaked, and those were joints that were made in the winter time when the thermometer was probably registering 12, 15 or 16° below zero, and we have dug up lead joints and found that 9 out of every 10 of them leaked. Of course, the percentage may be great, because the work was done by contract; but my experience has been that the cement joints will hold up and lead joints will not, in Schenectady.

MR. FRANK HELLEN (Rochester): Up to the present time I have always been a great admirer of the cement joints in the

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cast iron mains, up to and including 16-inch cast iron pipe. In fact we have had no trouble until this year with any of our cement joints, but of late we have had a great deal of trouble as we have found some 25 or 30 leaky joints in our 16-inch cast iron pipe.

These are joints which have never bothered us before, and some of the pipe has been laid 4 or 5 years, and was tested under 10-pound pressure, and the joint had been made 24 hours in all cases before the test was made. The pipe was laid on a solid foundation, and I know that it did not settle in any way so this could not be the cause of the joints leaking. Personally, I do not know how to account for, why the joints should remain tight for 2, 4 and 5 years, and then all of a sudden start leaking. From our past experience in Rochester, I believe that we will not lay any more 16-inch pipe with cement joints. We have had no trouble with our cast iron joints up to and including 8-inch. (We have never laid any 10 or 12-inch with cement joints.)

We use the Dyckerhoff cement in all cases, and are very particular to see that the cement is not defective before being used.

We have also in Rochester raised and lowered several pieces of 4 and 6-inch cast iron pipe, made with cement joints, and placed them back in the trench and tested same under 10-pound pressure and found none leaking. I do not think this is unusual at all—I think other companies have had this same experience.

This year we have made a systematic inspection of our gas mains of all sizes, that is we have had two of our best foremen walk all over the streets where gas mains are laid, and notice the sewers, manholes, dead grass, dead trees, and everything that would possibly show that there was a leak. Where dead grass was noticeable they would needle the same, and make a report to the Gas Street Department of any leaks found. In this way we have found a total of about 130 leaks, and some of them were very bad.

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I believe that this is one of the best things any company can do, and is something which every company should do each year, and I personally believe the leaks we have found will save us a good deal of work during this coming winter.

I am also of the opinion that this has had a great deal to do with the reduction of our leakage. Our leakage for the year 1913, up to date is a total of 15,000,000 feet less than a year ago; reducing all our mains to a 3-inch basis, our leakage per mile on the 3-inch basis will be about 70,000 feet per mile of main.

I mention this merely to show that our joints must be equally as well made as most of the cities, for a great many of the people who claim they have no trouble with cement joints will find that their actual leakage per mile of main is 25 to 100 per cent. more than ours is in Rochester.

Personally I am a believer in using the line drip pot in all cases. If at any time you desire to locate a main it makes it very easy to do so without reference to our gas main maps, and it also makes it very easy to sound the drip to show if any water is left in the drip pot.

In regard to the question of piece-work, I do not see how this system can be worked out. It is surprising to note the different conditions of the soil in which the men are working—how it varies from 12 to 25 feet apart.

I believe if you pay your foremen good wages, and make their positions better than they can get elsewhere, also pay your laborers as much if not more than the contractors are paying, that in this way you can get the pick of the laborers; show the laborers that their interests are yours and that you will do for them all that is possible. I know this has proven to be the case in Rochester, for last year we laid a total of about 5 miles of 16-inch gas main at a cost of 46 cents per lineal foot.

The great trouble with most of the gas companies in other cities is that they do not pay their laborers any more than is necessary, that is, they will pay from 2 to 5 cents less per hour

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than the contractors will pay, and for this reason only get the laborers the contractors will not use, and with this kind of laborers it is impossible to get results.

THE CHAIRMAN: We have just a few minutes before we will ask the gentlemen who read the papers to close the discussion.

MR. F. N. SPELLER (Pittsburgh): In referring to welding of gas lines in the field, Mr. Shattuck said nothing about the use of double length pipe, which is now on the market up to 12-inch size—40 feet long. It would be interesting to hear the opinions of those who have had experience, on this point.

Another thing that was not touched on, as prominently as it deserves, is the matter of cleaning the surface before coating. This should be done in such a way as to remove all loose dirt and scale,—otherwise the protective coating is of little use.

In Mr. Rice's paper I notice a statement credited to a prominent manufacturerer of wrought iron pipe, which criticizes one of the special features of "National" Pipe, in a manner very likely to mislead those not informed as to the process in question. The roll-knobbling method of working steel for pipe, which some have termed "Spellerizing," is merely a convenient means of kneading the metal and giving it better and more uniform physical properties; therefore it is not surprising that this competitor did not find any material difference between this and ordinary soft steel in chemical composition.

The references to corrosion by the same contributor are characteristic of practically all statements issued by the wrought iron interests, *viz.*: general opinions and hearsay, unsupported by comparisons of the various materials under the same conditions of service. It would be easy to refer the cases where steel lines have been in use for 20 years or so without damage due to corrosion, but this does not prove that steel is better than iron, nor is the reference to isolated cases, where wrought iron has shown long life, worthy of consideration, for any pipe may last only a few months or 50 years, depending on conditions.

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As an example of the kind of evidence which engineers demand, I submit some photos of a condenser coil recently removed from the Armour Packing House, Chicago, after 13 years service. As is frequently the case, both steel and iron pipe were installed together at that time and those who examined the pipe on removal report no preceptible difference in the pitting of the two.

This is another case, in addition to the many now on record, all of which point to the same conclusion as that expressed in Mr. Vincent's paper.

MR. L. R. DUTTON (Jenkintown, Pa.): For comparison of cement joints with lead joints on pipe under 10 inches in size, we have had in use for 15 years about 15 miles of pipe used on low pressure in which the cement joints were made with Mannheimer cement. In the 15 years we do not recall over one-half dozen leaks having been reported on pipe with cement joints. The leaks which developed were almost all during the winter months, and the breaks we had were from frost breaking the cast iron pipe where the pipe was porous. The leaks did not occur at the joints.

Last winter we had considerable trouble with leakage, and the most of this happened with cast iron pipe 4-inch and 6-inch in size which had been laid at the same time as the pipe with the cement joints, but the joints were made with lead, and at least 80 per cent. were found to be leaking. On high pressure wrought iron pipe line where the pipe had been installed around bends in the road and not properly protected, the frost in the ground caused breaks in the pipe back of the sockets, also at points where rubber insulated couplings had been installed

Our conclusion with the experience of laying the wrought iron pipe, if not properly protected in the trenches, and laying the cast iron pipe with lead joints, and cast iron pipe with cement joints, is that we have fewer leaks from the use of cement joints than in any of our other pipe lines.

MR. S. H. WALLACE (St. Louis): I had occasion to make

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some experiments on electrolytic conditions in St. Louis County. We had a pipe line of 6-inch high pressure carrying 40 pounds running near one of the sub-stations of the railway companies, and it has been our practice every 6 months to have to renew this pipe line for a distance of about 1,000 feet. I had occasion to relay the same underground, and I fell in on some fiber conduits. In looking that over it seemed to me this might be a good insulator. The fiber conduit is composed of several layers of thin paper thoroughly saturated with pitch, a layer of paper and a layer of pitch, and then put together under hydraulic pressure. We encased this pipe wth this fiber conduit, cementing the joints very closely with the pitch. The pipe has been in about 2 years and we have not had any trouble so far. We had another occasion to try it on some smaller mains, 2-inch, and 1-inch and a quarter, and the service drew my attention very particularly. In 7 weeks from the day we laid the service, the service pipe was eaten up. We encased that with fiber conduit. And we have not had any trouble since, and it has solved the problem. We have a standing roll where we intersect the car line and we lay the pipe line inside the fiber conduit.

On the cement joint proposition I have had an experience—the city was rebuilding or regrading a street for a distance of about 300 feet, and there was an excavation of about 8 feet. We took the pipe out and laid it on the bank with 3 tripods and connected it in at each end with 2 inch steel pipe for temporary purposes, and after the grading was done we laid that same line back in the ditch and made a test and it was still working. The pipe has been laid about 4 inches on cement joints. We found absolutely no trouble.

THE CHAIRMAN: I have been requested, gentlemen, to close the discussion of the paper at this time, so with your permission we will first hear from Mr. Rice.

MR. H. L. RICE (Aurora, Ill.): I do not disagree with Mr. Shattuck as to low points in pipe lines. Reading the paper on page 175 you will find this statement: "It is

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customary to grade pipe lines to the extent of avoiding an unnecessary number of pockets or low places."

It certainly is not necessary to have the same careful grade with high pressure as with low pressure mains. We put drips in for the first 2 or 3 miles. After that we record the low spots and do not put the drip pots in until we find they are necessary, for the reason that we found trouble in cold weather from the shearing off of the pipes. In one particular locality we lost several drip pipes with a consequent leakage, which was very objectionable. We took those drip pipes out and have never since had occasion to use them or go into the pipe at that point. It was certainly a good argument that drips were not necessary in that locality, although the low points are known. With a high pressure main where the moisture is well taken care of in the first mile, we started about a year ago to pump gas to a town where we had previously had a plant in operation and from which town we had been pumping out. In pumping out from this point we had not protected the line with baffle plates or tanks, and had not extracted the moisture, and this line was therefore full of moisture for a considerable distance. After reversing the pumping and bringing the gas from 30 miles distant, we took moisture from the end of the line for the first 3 months, but for the last 9 months we have taken no moisture out of the line, but the gas coming into this town has been absolutely dry, so dry in fact that we have a curious condition of naphthalene trouble, namely old deposits, drying up in the pipe and clogging temporarily simply from a condition of over-dryness and nothing else. That simply shows that at a distance of 30 miles, we are bringing in absolutely dry gas, and we have dried up a pipe line that had a lot of moisture in it.

The subject of welding should have been included in this paper. It was not included because of the inexperience of the writer, and the writer is glad it has been so well brought out in the discussion. Mr. Macbeth brings up the question of higher pressure on cast iron pipe lines. The statement

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on page 149 is that cast iron is not suitable for high pressure work for pressure exceeding 5 pounds in the first place, because of its porosity and second, because of the uncertainty of the joints. The question of joints has been pretty well taken care of in the discussion of lead wool. As for the porosity, the writer has very little information. The limit of 5 pounds has been a classic in high pressure work. It may be upset by further experience, and Mr. Macbeth's experience will be very interesting if he actually attempts to use 10 pounds on a cast iron main. Mr. Terry speaks of air versus gas for testing. On page 176, you will find the statement that in such cases air pressure may be resorted to for testing, but this is less reliable and many engineers prefer to test their pipe line with gas at a lower pressure than with air at the desired pressure. In our company we would not use air for testing high pressure lines under any consideration. We prefer to use gas at a lower pressure, rather than pump up with air to the pressure desired. Probably many of you have had the experience of ordering high pressure tanks, and have specified that they should be tested by the manufacturer with gas pressure, and he, confident in his own experience, disregards your instructions and has them tested under air pressure, and they leak immediately when you put gas on them, even though you use a much lower pressure than he does.

Mr. Jones brings up the question of 2 valves, and he spoke of 1 valve being used to take the place of the other when it fails. The abstract perhaps missed the point of the 2 valve station. It did not mention the vent, which is placed between the 2 valves. The object of the double valve station is that if a valve is nearly tight, but will not hold a high pressure of 25 to 50 pounds, it possibly in most cases will hold ordinary low pressure. By using 2 valves and venting you only get low pressure on the second valve, and this has worked safely with valves that were not absolutely perfect. All our valves have a blow-off at the bottom, and we blow out scale, and the black dirt which collects frequently and thoroughly, but never-

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theless we have found single valve stations are not effective, and we have had to go back some times 2 or 3 miles and close other valves, and open sleeves between to get a vent. This double valve station does that very readily, and so far as we have used it we are very well satisfied with it.

The discussion did not bring out anything regarding digging machines, which was rather a surprise to the writer, but of course they are new. The report of experience in the paper covered only 11 days on a new machine. This favorable experience has continued and we long ago paid for the first machine. We paid for it so soon that we bought another, and now we have bought a third, and we believe it is absolutely the solution of running long stretches of pipe line across country.

MR. G. I. VINCENT (Des Moines, Ia.): To the best of my recollection welding is not mentioned by any of the works. it was not mentioned in the paper. It is obvious from the Jones' plants which came in too late to be used. That is why it was not mentioned in the paper. It is obvious from the discussion here that it must be a rather satisfactory method of making steel pipe joints. Also, the double coating for wrought pipe mentioned by Mr. Jones was not reported by any of the plants, and I do not believe any of the larger companies are using it.

I think Mr. Bunker spoke of testing cement joints at very high pressure. As you all understand, my paper is simply a compilation of the data returned by a large number of plants. One of the conclusions is that ordinary forms of joints in cast iron mains are not to be depended on for high pressure, and therefore the necessity for testing them at high pressure does not seem to be apparent. In other words, the paper recommends some other form of joint to be used for high pressure without specifically going into what type of joint that should be.

Among the few things that are original in the paper was the discussion on the theory of the failure of large cement joints,

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and I have talked it over with a number of engineers, and submitted the calculations to a number of engineers, I think I am safe in stating now that under conditions that obtain in a climate like Des Moines, it is not practicably possible to make 30-inch cement joints in standard bells that will remain tight. I do believe it is possible to make a tight cement joint in large mains in a specially deep bell, because I believe that the failure is in the contact between the cement and the iron due to the shear set up by the difference in temperature between the top and bottom of the main. If the contact area between the cement ring and the cast iron bell or spigot be increased by increasing the depth of the bell, I am confident it will be possible to make large cement joints that will remain tight.

The paper, drawing from the data submitted, specifically states that cement joints can be satisfactorily made up to 12 inch in standard bells and are not to be depended on over that size.

The discussion rather developed into the relative merits of lead and cement joints, apparently assuming that condemning cement joints for large mains implied an approval for lead joints. The paper suggests in the summary that lead joints also are not to be depended on for large mains. The paper held no brief for either cement or lead joints.

A little discussion developed on piece-work. As I took it from the data of the men that are using it, piece-work in main laying, is used only in the ditching, in no case has it anything to do with the pipe laying, and I think the engineers that have tried piece-work in main work and other work, have found it to be satisfactory where it did not come in contact with the handling of live gas. That seems to be the point where they wanted to draw the line. It seems to be inadvisable to attempt any bonus system or piece-work, where live gas has to be handled, or even in making installations through which gas will subsequently flow.

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MR. WALTON FORSTALL: I would like to move a vote of thanks to Mr. Rice and Mr. Vincent for their papers.

The motion was duly seconded and carried.

Recess until 2 P. M.

AFTER RECESS.

The Chairman called the meeting to order at 2:15 P. M.

MR. WALTON FORSTALL: Mr. Simpson unfortunately could not be here, so I have been asked to read his paper.

PROTECTION OF STREET MAINS BY AN ADEQUATE SYSTEM OF INSPECTION.

Abstract.—For years each street and avenue in the borough of Manhattan has been patrolled on foot daily, about 30 men and 3 chief patrollmen being required. During 1912, 7,590 important items were reported, including leaks of all kinds, condensation spilled in streets, buildings torn down requiring the cutting off of services and removal of meters, settlement of street surfaces, box covers missing, excavations by other concerns, etc. Each of these reports cost about $3.00, but the money is believed to be well spent in prevention of accidents that would probably have occurred.

In Brooklyn the system is practically identical with that in New York, while in Philadelphia a similar inspection is in force, except that the streets are covered about twice a week and the men use bicycles. During cold spells, the Philadelphia patrol force is increased to admit of all pipe smaller than 6-inch being patrolled twice every 24 hours, and 6-inch and larger every two days.

In Chicago, all employees are required to report the tearing down of a building in addition to which the company has a system of furnishing house wrecking companies with postal cards by which they advise the gas company in advance of their intention to tear down buildings. In addition to this, they are periodically asked for this information.

In Boston it is felt that the districts are sufficiently covered by men in the several departments, and no regular system of patrol is in force. In Detroit systematic patrolling is confined to the streets in which are high pressure mains.

Probably the most dangerous class of work as far as gas companies are concerned is the construction of underground railroads. In New York the work was originally done by the open cut system, but the general clamor against traffic and business disturbance has resulted in the cut-and-cover method. This, which, as far as sub-surface gas

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property is concerned, is infinitely more dangerous, consists in removing the paving and replacing it with a tight wooden decking, under which the excavation and construction progresses, practically by tunnel methods, constituting a beautiful explosion chamber.

In New York every main on work of this character is killed and gas is supplied to the consumers from temporary by-passes laid in the gutter before any excavation is done. The large mains are carried on trestles above the sidewalk so as not to interfere with traffic, and valves are placed at intervals so that any section of main can be shut off in case of necessity. In addition to these precautions taken before the subway work is started, every foot of the street or avenue is patrolled day and night by specially trained uniformed inspectors, each of whom has a section about half a mile long and is provided with all appliances necessary in cases of emergency. The inspectors are required to ring time clocks at each end of their sections at short intervals, and are under the charge of a foreman and still further under charge of a general subway foreman. This branch of the work is considered so important that the position of subway engineer has been created with one of the best distribution engineers directly in charge.

As the openings other than for subway work are reported to the office, their locations are visited by the district foreman who report to the district superintendent on the advisability of assigning special inspectors. When conditions warrant, a competent man provided with all necessary tools and appliances is put on the work so as to take any necessary steps to prevent trouble in case of emergency.

Another class of construction work which requires constant vigilance and to which these special inspectors are assigned is that of excavation for building foundations. On account of the enormous value of land on Manhattan Island, all available space is utilized with the result that very deep excavations are made close to the curb line, and unfortunately, not always properly sheathed and braced. Where possible, the endangered mains are cut off, but where this cannot be done, special stoppers are placed where they can be inserted without delay. They are called locally "surface inserted stoppers," and are merely gas bags with long pipe stems inserted through previously installed standpipes brought to the surface and protected by ordinary street boxes.

On account of the rapidity with which news travels in small communities, the writer believes that the companies in such places will hear of any occurrence affecting their undertaking. He does not, however, recommend neglecting entirely the precaution of patrolling, and in the Yonkers district, the largest town supplied by the Westchester Lighting Co., the distribution system is gone over according to a sched-

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ule which calls for an inspection of each street once a month. In the other districts of this company, which are mostly suburban residence towns, there is no systematic patrolling on distribution lines. The transmission mains are patrolled daily for six months beginning October 1st, daily along the important lines where work is being done by other companies, and weekly as to the rest of the transmission lines. Where the mains are threatened, precautions similar to those in New York are taken. Where possible the company tries to have other companies do blasting in the morning so that there will be sufficient time to make repairs in case of damage.

With high pressure main, breaks promptly reported by citizens, are much more likely to occur than small leaks. The Western United Gas and Electric Company patrols its entire high pressure system once in the fall and once in the spring after the frost has left the ground, and also patrols different sections where breaks are suspected. The patrolmen watch for evidences of leaks, looking out particularly for smells and dead vegetation and also examine drains and culverts.

In Chicago, streets containing high pressure feeders are patrolled twice a year and feeder line vaults and valve basins constantly; in Detroit the high pressure lines are patrolled once a year, the work consisting ordinarily of an inspection for surface indication of leaks.

INTRODUCTION.

Let us assume at the outset that gas property, particularly mains and services, in the sub-soil of public streets and highways, requires protection. It is scarcely possible that anyone will dispute this fact. The important point for the consideration of distribution engineers is, therefore, the methods and devices to be employed for the purpose of insuring that this protection is intelligently obtained. As the writer is naturally more familiar with conditions existing in New York City, and as New York's problem in this respect is unquestionably as difficult as that of any of the larger American cities, it probably will be best to describe fully our method of handling the various phases of the question, and then to take up the manner of solving the problem in other cities.

It has been manifestly impossible to obtain the views of each and every American distribution engineer on the various divisions of this subject, but the hope is entertained that those whose practice has not been ascertained and mentioned herein and who undoubtedly have matters of importance to con-

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tribute in this connection will enter heartily into the discussion. This paper is not intended to be a lecture or to serve as a text-book, but rather is written for the purpose of developing a wider interest in one of the most important features of street main maintenance.

STREET PATROLLING OR LINE-WALKING.

For a number of years it has been the practice in New York City—and by New York City is meant the borough of Manhattan—to patrol and inspect each street and avenue daily. This work requires a force of approximately thirty patrolmen and three chief patrolmen, each of these patrolmen being assigned to a regular district and having a regular route laid out for covering it. The patrolmen start at one end of their route at 7 A. M. and finish up at about 4 P. M., thus allowing sufficient time to go to the branch office and make a report of the day's work. The principal duty of a patrolman is the reporting of gas leaks. These, of course, are telephoned immediately to the nearest emergency station, and the emergency crew is sent out to investigate. As a general proposition, however, the patrolman is required to report to the branch office every item of interest or value to the company. Before his assignment to patrol duty each man receives a certain amount of training and instruction in order that he may be properly qualified for the performance of his duties, and each patrolman carries a doctor's certificate to the effect that he is able readily to distinguish the odor of illuminating gas. During the period January 1st to December 31st, 1912, these thirty-odd patrolmen reported 7,590 important items, which included information respecting broken mains, leaking joints, services, lamps and drips; condensation spilled in streets, requiring disinfection; buildings being torn down, requiring the cutting off of services and the removal of meters; mains requiring protection or joints needing caulking on account of other companies' street openings; pickholes in mains and services, caused by other companies' work; settlement of street surface, indicating the possibility of damage to our sub-surface

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property; box covers missing or reversed, below or above grade, etc., etc.

Now, this patrol system costs a considerable amount of money in wages, but it is not difficult to demonstrate that this is expended wisely and well. Each of these 7,590 reports represents approximately a cost of $3.00; but is it not worth this sum to be in a position to properly protect our property before the occurrence of damage of any character? Let us

Fig. 1.

analyze the work of these patrolmen during the year in question. First, we have street leaks of all characters, of which a total of 642 were reported by patrolmen. It is difficult to imagine any distribution man questioning the absolute importance of securing leaks with promptness, or disputing the statement that it is worth many times $3.00 to receive early notification of the location of the same. Second in point of importance we have reports of depressions in the pavement, which,

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in New York City at any rate, always indicate the possibility of serious disturbance of our mains and services. One hundred and sixty-six cases of this character were reported by the patrolmen; and as evidence of the necessity of having such conditions promptly reported, let us glance at Figs. 1, 2, 3 and 4, presenting 2 cases in which such reports were *not* made. In the first case (Figs. 1 and 2) a 36 inch water-main developed a leak which washed out a large cavity under the frozen street surface, completely destroying all adjacent sub-surface

Fig. 2.

structures. Under average winter conditions, and certainly at any other time of the year, the patrolman would have discovered this condition from surface indications on his daily round, and immediately reported it to our emergency crew, and within a half hour our mains would have been secured or temporarily cut out, and the Water Department notified to take care of their property. Unfortunately the frozen ground

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was of sufficient strength to hold up street traffic and the patrolman could get no indication of the trouble below. Now, let us take Figs. 3 and 4, showing a similar case during the same winter. The photographs show damage enough, but do not relate the whole story, in that the series of explosions, which were the first indication of trouble, can only be described and not depicted. Here, again, the patrolman was not responsible, as a 3-foot crust of frozen earth was sufficient to hold up the surface, while our mains were washed out beneath.

Fig 3.

These are two illustrations of what could have happened in the other 164 cases had they not been promptly reported and take care of, for every case of pavement depression is potentially as serious as those above mentioned.

Another very important duty of the patrolmen is that of reporting buildings about to be torn down. We are all more or less familiar with modern methods of building demolition, and I am confident that no one will dispute the fact that it is

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worth at least $3.00 to receive prompt information in this regard, that we may be enabled to enter these buildings before the wreckers destroy such meters as may be there and also break off the services. Eight hundred and six reports of this character were turned in.

Still another important duty of the patrolmen is the reporting of excavations made by other companies, in which it is or may become necessary to properly protect our structures, for

Fig. 4.

contractors and many sub-surface corporations are notoriously and criminally careless with respect to the proper support and protection of gas mains which they encounter. Of course, we can institute legal proceedings if our property is damaged, but is it not more economical in the end to prevent trouble if possible and keep clear of the courts? And it is quite possible that as a result of damage to our mains some one may be killed. Though the damage may have been caused by others,

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are we not liable morally for having permitted the accident while conscious that it would have cost us but $3.00 to obtain information sufficiently in advance to have prevented the disaster?

Fig. 5 is a good illustration of what the average contractor considers proper and safe supporting of gas mains—10 or 15 feet of scantling, stuck in the ground, which the slightest jar or vibration will shake out of place! Five thousand eight hundred reports of this character were turned in by the patrol-

Fig. 5.

men, and it does not require much stretch of the imagination to see the value of the patrol system in this connection. The balance of the 176 patrolmen's reports consisted of miscellaneous items, such as drip and valve boxes above or below grade, which might cause accidents to vehicles or pedestrains; meter and housepipe leaks, which were reported to the patrolmen by citizens, janitors, etc., etc.

As already stated, the patrolmen have their own districts,

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and they soon become known to the residents thereof and also to the workmen of other companies. Their very presence among those other workmen undoubtedly is the cause of preventing considerable damage to the gas company's property.

As an incentive to diligence on the part of the patrolmen, every 6 months a tabulation is made of the reports which they have turned in—which, of course, have been checked by the branch office—and the patrolman in each branch having the highest rating for the period receives an increase in pay.

Now let us compare the practice in respect to patrolling and line-walking in New York with that of some of the larger American cities.

In Brooklyn, the system of acquiring information in this respect is practically identical with that in New York, and in the congested portions of Brooklyn Borough working conditions are as difficult as those encountered in Manhattan. It will not be necessary, therefore, to describe the Brooklyn Union Gas Company's system, for it would be merely a repetition of what has been noted with respect to New York.

The patrol system in effect in Philadelphia is quite similar to that in New York and Brooklyn, except that in place of covering each street and avenue daily, in Philadelphia a patrolman inspects a street about twice a week, and, while in New York and Brooklyn the patrolmen are required to walk over their routes, in Philadelphia bicycles are used. During spells of cold weather, the Philadelphia patrol force is increased to such an extent that all 2 inch, 3 inch and 4 inch mains are patrolled twice every 24 hours, and all 6 inch and larger mains once every 2 days. These additional men are required to walk over their routes in place of being provided with bicycles.

The duties of the Philadelphia patrolmen, or line-walkers, are, in general, to patrol the streets in which mains are laid or in which new buildings are in process of erection, for the purpose of gathering and reporting any facts that may be of value to the company. During severe cold weather, they also patrol their districts at night. Their work is checked up by a

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system of reports, which cover in detail all inspection work and indicate the time of all stops made—the report being really a diary of the patrolman's work. As in New York and in Brooklyn, the discovery of a condition requiring immediate attention is telephoned to the office.

In Philadelphia a consecutive record of street openings made by foreign companies is kept on cards made out by the patrolmen. This enables the gas company to trace back any damage to its property caused by other companies working in the street. Philadelphia patrolmen are also required to inspect all street openings for which their company is responsible, and to report to the office, sufficiently in advance, all locations at which signal lamps or danger flags may be necessary so as to permit of the lamps and flags being placed the same day. They are also required to investigate service conditions where the footway is being paved or repaved, in order to allow prompt renewal of all services or running of new ones where necessary. In the matter of buildings about to be torn down, it is the duty of the line-walkers to obtain data as to service location and information as to the location, sizes and numbers of the meters there. Another valuable fact gathered from the patrolmen's reports of street openings is the location of gas company's sub-surface property. In New York this is obtained by draughtsmen detailed to cover all openings involved; in Philadelphia the information is obtained directly by the patrolman and turned in on his report.

In Chicago, a rule of the company requires that all employees, when noting the tearing down of a building, with the possibility of injury to the company's property, shall make a report of the same immediately. In addition to this, the company has a system of furnishing house-wrecking companies with postal cards, by means of which they may advise the gas company in advance of their intention to tear down buildings, and they are periodically requested for this information.

In Boston ,the gas company does not maintain a force of inspectors for the systematic patrolling of streets, as it is felt

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that their districts are sufficiently covered by the men of their several departments in the performance of their daily duties to keep the company in touch with all work which might in any way affect its property.

In Detroit, the systematic patrolling of streets in which the company has mains is confined to the high pressure system, and the method followed in undertaking this work will be described later.

RAPID TRANSIT SUBWAY WORK.

Probably the most dangerous class of work, so far as gas companies are concerned, now being undertaken in some of the larger American cities, is the construction of underground railroads; and in this respect a vast deal has been learned by bitter experience during the past ten years. The practice of gas companies in cities where work of this character is being or has been conducted is at the present time so nearly standardized that a description of the methods employed for insuring absolute safety in New York, where an enormous amount of this work is at present under way, will serve to thoroughly cover the ground. No other undertaking in the history of New York City, so far as underground work is concerned, has caused the distribution department so much anxiety and loss of sleep, and the prevention of serious accidents has only been accomplished by extreme precautions and eternal vigilance. This work was commenced in 1901 but at that time it was done mostly by the open-cut method. The general clamor, however, against traffic and business disturbances caused by this type of construction has resulted in recent years in the prosecution of the work by what is known as the cut-and-cover method, which, so far as sub-surface gas property is concerned, is infinitely more dangerous. For the information of distribution men who have as yet been fortunate enough not to have experience in work of this character, perhaps a description of the two methods mentioned would be of interest, for subways seem to be constantly increasing in favor and are bound to come in time to all of the larger cities. The "open-cut" method,

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as its name implies, consists of opening the entire street from the surface and merely decking over a small portion of the same for vehicular and passenger traffic. While this method allows for considerable serious damage to gas mains if extreme vigilance is not maintained, yet the danger of serious explosions is greatly reduced as the cut is naturally well ventilated. The "cut-and-cover" method, now in general use in the more congested portions of cities, consists in first removing the street

Fig. 6.

paving and then replacing it with a tight wooden decking, under which the excavation and construction progresses, practically by tunneling methods. It does not require great imaginative power to figure how disastrous an explosion could occur were a gas main to be broken or even to leak for a short period of time in this beautifully constructed explosive chamber; and as an instance of the thousand and one different and ever-present possibilities of a serious leak, Figs. 6 and 7 show the damage

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done by an overcharged blast on New York's Lexington Avenue Subway at 87th Street. Had our mains at that point not been by-passed on the street surface, there would have been over 2,000,000 feet of gas per hour emptying into this opening. When this accident took place, as shown in the photographs, street traffic was stopped for several days, but not even a slight odor of gas was detected. Why? Because we have made it an inviolable rule to kill every underground main

Fig. 7.

on work of this character, and to temporarily by-pass the same with wrought-iron pipe above the decking. In this position and constructed with this material, these temporary mains may be readily inspected and cared for and are subject to the minimum possibility of damage. Again, in this illustration, attention is called to the temporary by-passes, which may be easily seen, and which are absolutely undamaged in every respect, not one consumer having been shut off even for 5

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minutes. Just contrast these by-passes with such of the original underground mains as can be seen where the planking has fallen into the cut. They are reduced to scrap-iron. This case is typical of one of the dangers of subway construction, but damage as great as that shown here could easily be caused by the explosion of a small quantity of gas leaking from a main or service under the decking; and while we have always been convinced that by-passing work of this character was

Fig. 8.

absolutely necessary, we are indebted specially to this particular accident in that it brought vividly before the minds of the city officials having charge of this class of work the absolute necessity of the same, as they formerly regarded by-passing a foolish and wholly unnecessary precaution. Fig. 8 shows the method of running by-passes along the street decking. These temporary mains are laid before any excavation is done, and are carried back in the side streets to a point of safety. As

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soon as the services are transferred to the by-passes the mains in the street are immediately cut off and capped. Most of the contractors engaged in building subways in New York City now consider this protection work so important that they are unwilling to assume the risk of excavating until the by-passes have been installed.

In addition to the temporary by-passes laid on the street decking it is necessary to take care of all of our larger mains—

Fig. 9.

both distribution and transfer—which are interfered with in any way by subway work. Figs. 9 and 10 show the method of carrying large mains on trestles along the route of the Broadway Subway in the borough of Manhattan. These lines are laid in addition to the regular curb by-passes and have been placed overhead so as not to interfere with street traffic. As can be seen in Fig. 9, valves are provided at intervals in order that any section of these mains may be quickly shut down in

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case of necessity. Figs. 11 and 12 show by-passing of a similar character in 138th Street, borough of The Bronx; and, as can be seen from the illustrations, this work has been completed before the street paving has even been disturbed. Fig. 13 shows the method of carrying large distribution and transfer mains across the Lexington Avenue Subway excavation,

Fig. 10.

the main in this case being 36 inches in diameter. The apparent sagging in the center of the span is due to the photographer and not to faulty construction, as the pipe is held rigidly in place by the suspension cables. Wherever our mains cross the line of the subway work and their services cannot be temporarily dispensed with, this method is used.

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So much for the precautions taken before the work is started; but we dare not permit our vigilance to stop here. Every foot of street or avenue where subway work is in progress is constantly patrolled, day and night, by specially trained uniformed inspectors. These inspectors have each a section, approximately a half mile long, and on each section there is a tool-box containing all the necessary tools, wrenches, stoppers, etc., which might be needed in case of emergency.

Fig. 11.

The inspectors are required to ring time-clocks at each end of their section at short intervals, and they are under the charge of foreman inspectors on each shift and still further under the supervision of a general subway inspection foreman.

This subway work is now deemed so important that the position of subway engineer has been created with one of our best distribution engineers placed directly in charge, and under the present method the work has been under way for nearly

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2 years at the date of writing without one single disturbance to our property. We have endeavored to make the system as nearly "fool proof" as possible, and apparently have succeeded.

SPECIAL INSPECTION ON WORK OTHER THAN SUBWAY WORK CAUSING EXTENSIVE STREET DISTURBANCES.

As before stated, in New York the regular patrolmen turn in daily a list of all street openings made by others than the gas company on their routes, and these locations are turned

Fig. 12.

over to the various district foremen, who inspect the same and report to their district superintendent on the advisability of assigning special inspectors. Wherever conditions warrant it, a competent gas man is placed on the work, or on several different jobs if they are located within a short distance of each other, to insure that no damage is done to our sub-surface property. These iuspectors are provided with all necessary

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tools and appliances so that in the event of the occurrence of damage they are able immediately to take such steps as may be necessary to prevent trouble and interruption of service. The presence of these special inspectors is of great benefit to us, as the very crowded sub-surface conditions existing in most of the streets of Manhattan make it absolutely certain that some underground property will suffer during any underground construction work. Before it became the policy to

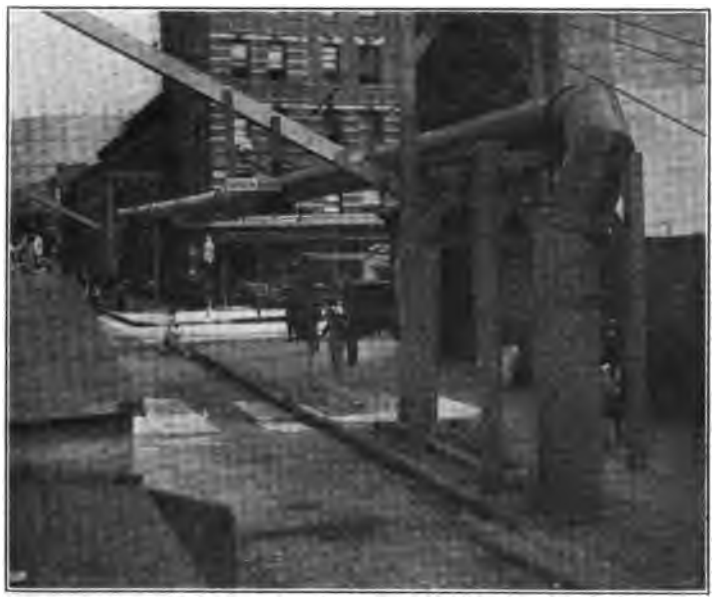

Fig. 13.

assign these special inspectors on all street openings it was quite common to find our mains built into manholes or having other heavy sub-surface structures resting upon them. Where blasting operations are in progress in sufficiently close proximity to our structures to be liable to cause damage, stopper-holes are always tapped in the mains, and before each blast the inspector inserts the stoppers so that in the event of a

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break no great amount of damage can be done. Of course, more or less friendly relations exist between the gas company and the other sub-surface corporations, and there is a considerable amount of giving and taking so far as underground space is concerned; but the presence of these inspectors is of great assistance toward preserving a proper balance and insuring that we do not give more than we take.

Another class of construction work, which, though it does not directly affect the street surface to any great extent, requires constant vigilance and to which these special inspectors are assigned, is that of excavation for building foundations. Land is enormously valuable in Manhattan Island, and consequently when buildings are to be erected the architects endeavor to make use of all available space both in a horizontal and a vertical direction. Therefore, we generally have the proposition of a very deep excavation extending to or within a few feet of the curb line and unfortunately not always properly sheathed and braced. Wherever possible, we consider discretion the better part of valor, and cut off all such mains as are liable to be endangered by a failure of the sheathing. In many cases, however, this cannot be done, and stopper-holes are tapped in the mains at a safe distance on either side of the excavation, and the necessary stoppers are placed where they may be quickly secured by the inspector and inserted in the mains with the minimum amount of delay. For work of this character we have recently developed what we call for lack of a better name a "surface inserted stopper." This is merely an ordinary gas-bag with a long pipe-stem, and it is inserted through a standpipe that has been previously brought to the surface, and is protected by an ordinary street box. Figs. 13 and 14 will show more clearly than any description the method of using this device, which is of considerable value, allowing, as it does, the repaving of the street surface as soon as the standpipe has been placed and rendering unnecessary the construction and maintenance of a temporary wooden manhole. The street boxes over these standpipes have a special distinguishing cover, which enables us to locate them readily.

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Another benefit derived from this type of stopper is the fact that when the standpipes are once placed in the main they

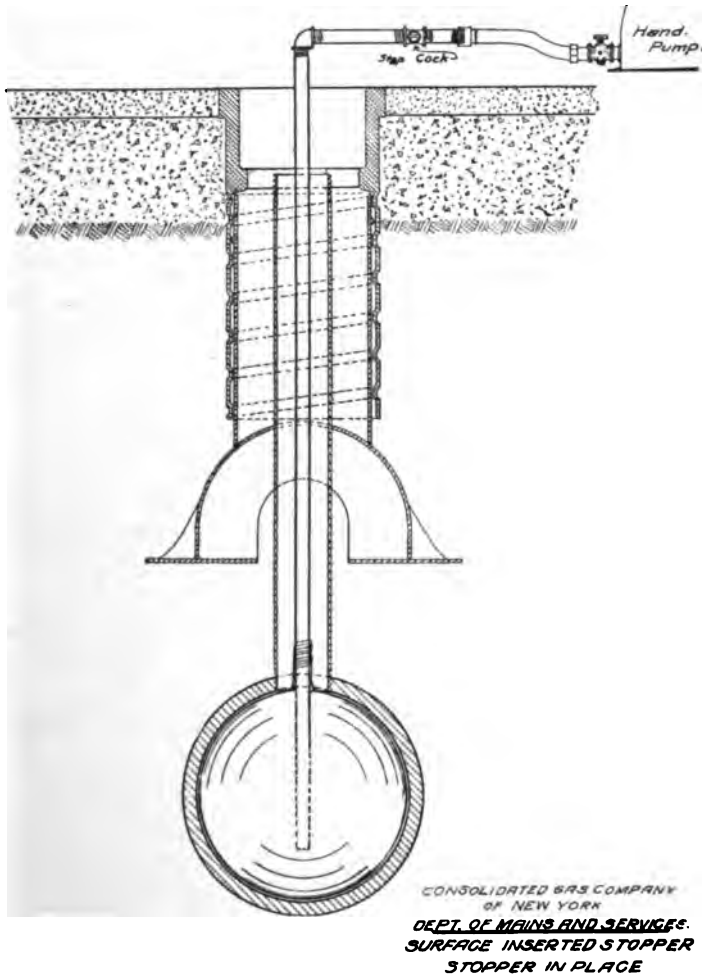

Fig. 14.

are there to stay and may be later used at any time as temporary valves.

It will not be necessary to show specimen photographs of

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the damage which has been caused to underground structures by improperly secured building excavations, for I am certain that every distribution man present has had more or less expe-

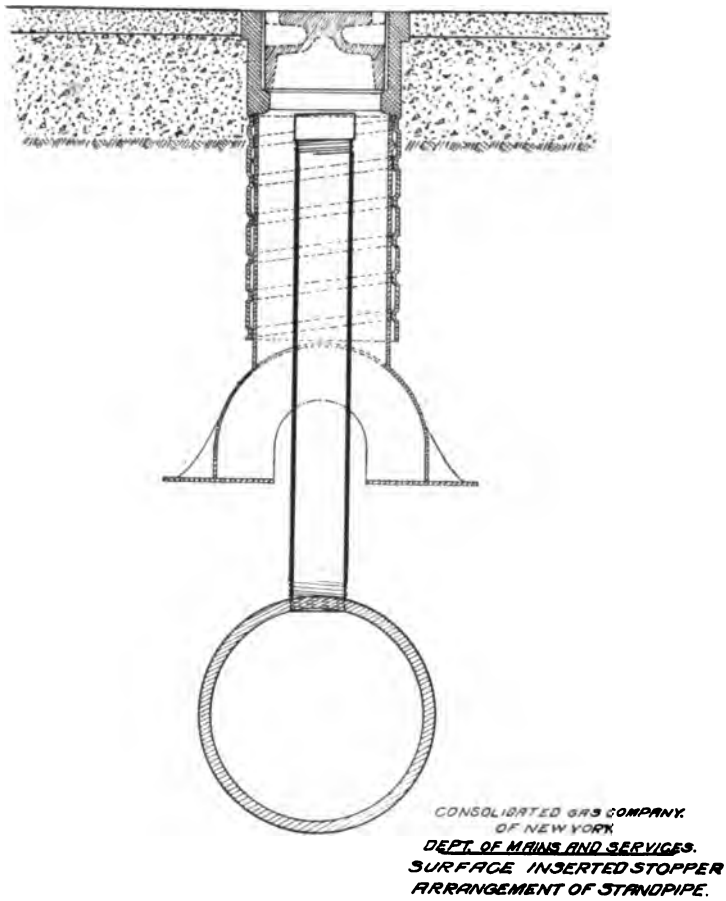

Fig. 15.

rience in this respect. I was considerably amused by an item in a British gas publication describing an occurrence of this character, resulting in the breaking of three mains. The article

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stated that "The first man arrived at 1.30 A. M. and the final stopper was inserted at 8.30 A. M., stopping all escape of gas," and closed with the statement—"The dangerous work was successfully carried out without an explosion occurring, without the gas firing, and without injury to anyone." If our British friends had expended five or ten pounds in taking some of the precautions above described, the final stopper could probably have been inserted in five minutes instead of five hours after the occurrence of the accident, and at least an enormous waste of gas would have been prevented. The general practice followed by most of the larger gas companies with respect to the protection of their property where extensive sub-surface work is being undertaken is practically identical with that above described in New York, and need hardly be enlarged upon, except that in the city of Chicago, in which the soil is of such a character as to make building foundation work exceptionally dangerous, a special corps of inspectors, under the charge of an engineer, is assigned to this work. This engineer inspects all building excavation work and watches caisson sinking for evidences of quicksand, taking levels on the street surface for signs of settlement. He indicates the necessary action to be taken for the protection of mains and services, which may mean the simple precaution of providing the necessary stopper-holes or perhaps the cutting off and capping of all mains adjacent to the building.

INSPECTION OF SUB-SURFACE PROPERTY AS ADVISABLE FOR SMALL CITIES AND TOWNS.

As a general proposition news of any character travels with a rapidity inversely proportionate to the density of population, and the application of this fact to the gas business would indicate in a measure that the gas company officials in the smaller towns and outlying districts, being naturally acquainted with a considerable larger percentage of the population than those in the larger cities, will receive news in any way affecting their undertaking with a greater degree of facility. However, I do not attempt to assert that in streets running through sparsely

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populated territory it would be policy to neglect entirely inspection of mains for leaks or other indications of trouble. We have an example close at hand of a suburban company supplying gas to a number of cities and villages in Westchester County—the Westchester Lighting Company. In the largest city supplied by this company—Yonkers—the distribution system is systematically patrolled according to a schedule which provides for the inspection of each street once a month. In the other cities supplied, which are mostly suburban residence towns, no systematic patrolling of distribution mains is done. The transmission mains, which are of course of great importance to a company of this character, are patrolled daily during 6 months starting October 1st, and for the last 2 weeks in December, during the peak load, are also patrolled on Sundays. During the balance of the year, the important sections of transmission mains along which work is being done by other companies are patrolled daily; the balance of the transmission system being patrolled on a weekly schedule. Where other companies are doing extensive work along the lines of transmission mains and these mains are liable to be damaged thereby, special inspectors are placed on the work to watch the company's interests ,the number of these varying according to the importance of the main and the risk in which the same is placed.

In the event of sub-surface work being done along the line of distribution mains, an inspection is made daily by a competent man, and as a general proposition stopper-holes are provided so that in the event of damage the main may be quickly shut off.

Wherever possible, the Westchester Lighting Company endeavors to have foreign companies do their blasting in the morning so that in case a main should be broken sufficient time will be available for the repair of the same before the load comes on at night. It has been the experience of this company that unless they take extreme measures and are exceptionally careful in co-operating with others whose structures

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are encountered during construction work on the part of the gas company, it is practically impossible to obtain co-operation in return from them; and this co-operation is of great importance to a company supplying a large suburban territory.

It was the intention of the technical committee to have this paper contain a recommendation for a method of inspection which could be successfully adopted by the smaller gas companies, but unfortunately the writer finds this to be an impossible task. Conditions vary greatly in different sections of the country, and it would hardly be possible to suggest any system of inspection or patrol which would not have to be greatly modified before being of service in any particular locality. The engineer in charge of the distribution system must judge for himself the risks involved and then make certain that every possible precaution is exercised to avoid serious damage from leaks and breakage, which are certain to cause interruption of service and possibly loss of life.

INSPECTION AND PATROL OF HIGH PRESSURE MAINS.

High pressure mains are of a somewhat different character than low pressure, inasmuch as breaks in the main are considerably more likely to be found than a number of small leaks, and these breaks, owing to the considerable volume of gas escaping, are ordinarily detected and reported by citizens at once.

The Western United Gas and Electric Company patrols its entire high pressure system twice every year—once in the fall, before cold weather; and again in the spring, after the frost has left the ground. In addition to these periodic inspections, this company also patrols different sections of their lines from time to time when breaks are suspected. These latter patrols are not as thorough as those in the spring and fall, as they are made only in the event of a break, and are confined to the discovery of the same. In the periodic inspections a certain number of men who are familiar with the mains are required to walk over the streets in which the mains are laid, paying special attention to any indication of leakage either from smell

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or from dead vegetation. The patrolmen also examine all culverts and drains which are crossed by the mains, and organized leakage work by barring is done when the aggregate amount of all the small leaks appears to warrant it. Many of the towns supplied by this company at high pressure are under the control of reducing regulators, which maintain a constant pressure of from 8 to 10 pounds. At the outlet of these regulators connections are provided for a Westinghouse high pressure meter, and once a year a test is made by connecting up this meter at the hour of minimum consumption. After an experience of some 14 years the Western United Gas & Electric Company considers patrolling as described above of sufficient importance and value to be systematically carried out.

In Chicago, streets containing high pressure feeder lines are patrolled twice a week, and the feeder line vaults and the valve basins are constantly inspected by a special vault inspection crew, equipped with a motor car.

The Detroit City Gas Company patrols the streets containing high pressure mains once a year—usually late in the fall. This work consists ordinarily of an examination of surface evidences of leaks, such as partially destroyed grass and trees or the presence of gas in the manholes of other sub-surface conductors. Where evidences of leakage appear frequent, organized barring over the affected district is usually resorted to.

In closing, the writer wishes to extend thanks to the distribution men of the various companies mentioned herein, from whom a considerable amount of information was obtained ;and also to repeat and emphasize the statement made at the beginning, that this paper is written primarily to promote discussion on a very important subject.

THE CHAIRMAN: Gentlemen, we have just listened to an excellent paper written by Mr. C. C. Simpson, Jr., Mr. Forstall reading the paper, and I would like to announce at this time that Mr. Simpson should have been here to present the paper, and by his company was allowed that privilege, but on

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account of his feeling that his duties at this time necessitate his presence in his city, he decided to stay at home rather than to be with us. It was a very great trial to him perhaps, in fact, I am sure it was, to be absent, but I think we all appreciate his sense of duty to his company in remaining home at this particular time.

Now, we will listen to Mr. J. A. Gould's paper, entitled, "Protection of Street Mains by the Intelligent Use of Underground space." Is Mr. Gould present?

MR. FORSTALL: Cannot we start to discuss this paper, and then suspend when Mr. Gould comes in?

THE CHAIRMAN: Yes.

MR. C. E. REINICKER (Chicago): I want to correct a false impression that the abstract has created. In Chicago we have quite a large mileage of feeder lines in which gas is carried at 5 pounds pressure. Those feeder lines are patrolled twice each week, every foot of them, instead of twice a year as it is stated in the abstract. The distribution vaults are visited at the same inspection and are also thoroughly inspected by a special crew once each week. This provides inspection much more frequently than the few times stated by the abstract.

MR. WALTON FORSTALL: I believe this is the first paper on this subject that has ever been presented to a gas association. I consider that it is very timely, both from the standpoint of the large and of the small gas company: Only the companies located in large cities can afford the expense incurred in New York and in Philadelphia. Fortunately, however, it is only in large cities that such expense is needed. On the other hand, the smaller companies cannot afford to ignore entirely this question of street main inspection. I believe that there are few companies so small as not to profit by a certain amount of systematic line walking during winter weather. In Pennsylvania, the inspection of street mains has been very much to the fore since the supreme court decided, in 1908, that the Borough of Kittanning had the right, in the exercise

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of its police power, to tax the gas company for the inspection of its mains by the police force of the borough. In this case, and also in the case of Erie, which followed soon after, I do not believe that the *amount* of the tax was brought in question, though in both cases $30 a mile per year was charged. Last year, however, at Allentown, the gas company offered evidence to show that the figure of $30.00 a mile was absolutely unreasonable, and as a result $12.00 per mile was fixed.

I do not understand that the $12.00 was what the company thought was reasonable, but it was the figure they finally settled on as a compromise.

This, however, is too high, because our Philadelphia costs are about $5.00 per mile per year, and these costs, as shown in Mr. Simpson's description of the Philadelphia system, include work which would not be done by the city's police force. As decisive evidence that the courts will take cognizance of reasonable costs for this inspection can be cited the recent decision of the Pennsylvania Supreme Court against the Borough of Kittanning, where, its having been shown that as a result of a number of years of this inspection, that the charge was in excess of the cost, the attempt of the borough to collect its former charges has been over ruled and a new trial ordered.

In view of the above, it seems to me that in Pennsylvania, and probably also in the other states, for the idea of raising taxes by charging for the inspection of gas mains may easily prove fascinating in places outside of Pennsylvania, it would be very wise for the gas companies to start an adequate inspection system, no more nor less expensive than the local conditions seem to demand. The main point is that each company should be able to show that it has a *definite* inspection system, costing a certain, amount of money. In this way, I believe that not only will the company benefit by a decrease in expense due to street leaks, but also will be in a proper position to defend itself against unjust taxation. Incidentally, it might be stated here that the Pennsylvania Supreme Court

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has ruled that a gas company is required only "to maintain such a system of inspection as would ensure reasonable promptness in the detection of all leaks." Therefore, another advantage from an inspection would be a better defense against claims due to street leaks.

Only large cities are apt to have subways, but small cities may at times be the theatre of more or less extensive excavations. It cannot be too strongly emphasized that a gas company should, in all cases of extensive excavations, put out of service any mains in or close to the excavations, caring for any absolutely necessary gas supply by overhead pipes, preferably of steel. In Philadelphia, we believed that we could, with perfect safety, save the Transit Company a large expense by leaving in the ground certain gas mains not in the excavation, but close to it. As a result, due entirely to very careless shoring by the subway contractor, there was a gas explosion, for which our company was held to be legally responsible and forced to pay a large sum of money.

In any city where there are many sub-surface structures, I consider it very important that the gas company secures, by its linewalkers, freedom from unnecessary interference with. and undermining of, its structures. The higher officials of the various companies using the streets are, of course, all anxious to avoid damage to the structures of other companies, but the actual working foreman is strongly tempted, when he is cramped for room, to encroach upon the existing structures, and here is where the linewalker is a valuable protection.

In Philadelphia, since the cold weather of 1912, we have been trying to differentiate between our summer and winter linewalking. In summer, the principal reason for linewalking is to guard against openings by other people that would affect our structures. In winter, however, the number of openings are comparatively few, and the main object in linewalking is to ensure prompt knowledge of leaking structures. Therefore, as all street leak records show that the greatest trouble is

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experienced with small mains, it is advisable in winter to patrol mains 4 inches and smaller very much more frequently than the larger mains. Such a differentiation of the work is productive of great economy, as compared with a system by which all of the mains are inspected as often as the small ones, and at the same time affords the requisite protection.

THE CHAIRMAN: Gentlemen, we have with us now Mr. Gould. The title of his paper is, "Protection of Street Mains by the Intelligent Use of Underground Space." We would be pleased to listen to Mr. Gould at this time.

Mr. J. A. Gould then read abstract of his paper.)

PROTECTION OF STREET MAINS BY THE INTELLIGENT USE OF UNDERGROUND SPACE.

Abstract.—The laying and maintaining of street mains in the congested districts of large cities is one of the serious problems of the distribution departments of gas companies, not the least of the troubles being the leaks and breaks caused by interference with the pipes by other companies. The problem is infinitely more complicated now than it was formerly when there was only a line of sewer pipe in the middle of the street with a gas pipe on one side and a water pipe on the other.

A long step toward avoiding present troubles would be to devise some system for assigning proper locations for all sub-surface structures in streets likely to become congested; but even if such a scheme should be in force serious trouble would develop unless the structures are laid so that those put in first shall not be undermined by subsequent work.

Under present conditions, valuable space is wasted by one party taking up more space than necessary or by claiming undue clearance. Some have an unfortunate habit of always locating their pipes half-way between existing structures so that the next company has the choice of two contracted spaces and will have to crowd both of his neighbors.

If there could be some experienced, fair minded and tactful official or board with power to decide upon the location of all pipes and conduits, conditions would be much simplified. An example of the possibilities in this line was had in Boston in one of the engineers of the Transit Commission who for several years was assigned the duties of supervising the relocating of all pipes and conduits over the new subways. Now all permits for new mains have to be passed by the various city departments in charge of the city's underground structures with a view to protecting the municipal property. But unless there is a thor-

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oughly settled policy as to locations, a change in the personnel of the departments controlling such locations may make radical changes in the policy.

But above all things, the problem of maintaining existing pipes in a safe condition is the most serious one for the gas company. A particularly dangerous condition is that in which a pipe is built into a manhole while the adjacent lengths rest on soft backfilling. The pipes may be so covered or crowded by new structures that it is impossible to caulk the joints, and large bills for damages may be incurred by driving bars or picks through electric cables while making necessary repairs.

It is conceded that with few exceptions the gas company has few rights that the city is bound to respect, and has to change at its own expense any pipes which might interfere with the work of the city or state, although in many cities the companies can collect damages from contractors on city work who injure their pipes. One important exception to this custom of requiring companies to move their pipes in a city in which the company is recompensed for moving its mains on account of subway construction.

Philadelphia comes as near as any of the largest cities to having a standard system of locations for pipes, sewers and conduits, and most of the underground structures have definite locations assigned by the Board of Highway Supervisors. Unfortunately this plan of standard locations often receives a setback through the fact that the three city bureaus installing underground structures take any location they wish without consulting the board.

The authorities of one very large city have recently attempted to establish a Bureau of Sub-surface Structures, designed to locate and map all existing structures and to assign locations for new work. Up to the present time but $^1/_7$ of 1 per cent. of the territory has been plotted. About 25 years ago a similar scheme was tried in Boston, but the plan fell into disuse through lack of appropriation. The gas company of one city was required to file plans annually at the city hall showing locations of mains laid, but it is questionable if reference was ever made to maps. It may be practical for some of the more modern cities to start such a system and to derive practical benefit from it; but where gas and water mains and sewers have been laid for 90 years, it is not easy to establish and maintain without a large annual expenditure, and for this reason such schemes are likely to come to an untimely end.

The laying and maintaining of street mains in the congested districts of large cities, is one of the serious problems now confronting the distribution departments of gas companies.

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If the trouble was confined to the laying of such pipes, it would be serious enough, but would be endurable for the brief period when we are laying the main, but the maintenance of these pipes is with us day and night, winter and summer, and the responsibility accumulates with each additional main we lay.

If we could eliminate the breaks and leaking joints caused by the interference with our pipes by the pipes, conduits and structures of other companies, the life of the men responsible for the maintenance of our pipes would be much happier and the maintenance expense would be much more satisfactory to our directors, than it is now.

The development of public utilities that require the use of the public streets has been so marked in recent years, that we may well sigh for the old-time conditions, when there was only a line of sewer pipe in the center of the street—a water main 6 feet from the north curb—a gas main 6 feet from the south curb and perhaps the rails of the horse cars in a few of the main streets.

Now the Sewer Department has the double system of sewers, one for house drainage and one for surface drainage. The Water Department has its ordinary distributing mains, a duplicate system of high pressure mains for fire service and its reinforcing feed mains.

The electric business has developed rapidly until there are now nearly a score of different varieties of wires buried in our streets, among which are found the following owners:

Street Railway Company's feed and return lines.
Electric Illuminating Co.
N. E. Telephone and Telegraph Co.
American Telephone and Telegraph Co.
Western Union Telegraph Co.
Postal Telegraph Co.
Telepost Co.
Fire Alarm Service.
Police Signal Service.
Boston District Messenger Co.

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Automatic Fire Alarm Co.
Electric Protective Co.
Holmes Electric Protective Co.
Mutual District Messenger Co.
Stock Quotation Telegraph Co.
United Telegram Co., etc.

Several of these larger interests, like the Street Railway Co., the Lighting Co., the Telephone and the Telegraph Cos., have separate conduits, while nine of the companies using low voltage combine as the Low Tension Wire Association and their wires are laid in a common conduit.

These electric conduits may be of small cross section, but their manholes are built on too liberal a scale, so they encroach upon the neighboring pipes and make serious complications.

In addition to the electric conduits, we have had the conduits of the heating company, followed by those of the freezing companies.

The pneumatic tubes for the U. S. mail service and parcel delivery are also troublesome neighbors, as they are exacting in their requirements as to line and grade.

Now the requirements of the street railroad have outgrown the capacity of its surface lines and require either the elevated system with its large underground piers, or subways, which tear up all the existing gas pipes and most of the other structures.

The city catch basins, which occupy a portion of the sidewalk and at least 3 feet of the roadway, still further reduce the available space; and in the business districts the practice of occupying the space under the sidewalks for basement areas, or coal holes, still further reduces the area available for pipes and conduits.

One very serious condition that confronts those gas companies that are not municipal plants, is that they have no permanent rights in their locations that the city or State is bound to respect when the latter want to do any work with which our pipes conflict.

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This has been strongly brought out in one class of work—that is, the construction of a duplicate sewer system. When the storm water sewers are built in streets where the old sewer is in the center of the street, the water main on one side and the gas main on opposite side, the city naturally locates its new sewers not on the side where it will disturb the water pipe, which is a municipal pipe, but on the side of the gas main, with the result that miles of such gas main must be relaid. This makes constant trouble and expense for the gas company.

Another unfortunate fact is that most of this sewer work is let in small jobs to small, irresponsible contractors, who have no interest in properly supporting or backfilling their trenches and the neighboring gas pipes have to suffer.

This trouble from the building of storm water sewers is avoided in new streets now being piped, by following the rule that the gas mains shall not be laid until the main sewer and water main have been laid. The gas main is then located between the two. This location is a happy one for the gas pipe, provided the sewer and water trenches have been carefully backfilled.

Unfortunately there are hundreds of miles of older streets that were built and piped before the city had adopted the duplicate system of sewers, so there is trouble ahead of us for several years.

The reciting of present conditions becomes a dreary tale of woe and the important thing is how are we to improve matters in the future?

A long step towards avoiding our present troubles would be made if it were possible to devise some wise system for assigning proper locations for all sub-surface structures in all new streets that are liable to develop into congested districts, or that will be occupied in time by a large variety of pipes and conduits; but even if such a scheme should be in force, serious trouble would probably develop unless these structures are laid in their proper sequence, so those first laid shall not be undermined by subsequent work.

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Under present methods, valuable space is wasted by one party taking more space than is necessary, and, by claiming unnecessary clearance for his own convenience, force other pipes into contracted areas. For instance, the parallel clearance demanded by different water departments ranges all the way from 6 inches to 12 inches in one city to 5 feet in another.

Some have the unfortunate habit of always locating their pipes half way between existing pipes, with the result that the next fellow has the choice of two contracted locations and, whichever he chooses, he will crowd both his neighbors, while if his predecessor had been wiser, there would have been room for all of them.

If there could be some experienced, fair minded official or board, who would have the power to determine just where all pipes and conduits shall be located, so that each structure, whether owned by the city or a corporation having legal rights in the street, would be given proper location, conditions should improve greatly. This official should be familiar with the laying and maintaining of all these structures, so as to intelligently locate them for the best interests of all concerned, and should be free from all bias or prejudice for or against every interest involved.

Such a position would be no sinecure and would require tact and horse sense to adjust conflicting interests and do justice to all.

In Boston, we have had a sample of the possibilities in this line in one of the engineers of the Boston Transit Commission, who, for several years, was assigned the duties of supervising the relocating of all pipes and conduits over the new subways. This engineer had previous experience on telephone conduits, pneumatic tubes and, best of all, the laying of gas mains, so his success is not to be wondered at.

The method now in force in Boston for obtaining a permit for a new main is as follows:

The Engineer of Distribution compiles a plan showing all existing structures in the street and indicates the desired location of the new pipe. A blueprint is sent with the application

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to the office of the Commissioner of Public Works and the location is approved successively by the Engineer of the Sewer Division, the Engineer of the Water Division, the Engineer in charge of grades and catch-basins and finally by the Division Engineer in charge of Highways, who endorses the application and the Permit Clerk issues the necessary permit. This supervision is only to protect the municipal structures, regardless of its effect on the interests of other corporations.

Unless there is a thoroughly settled policy as to the locations to be given certain pipes, we find that a change in the personnel of the departments controlling such locations may make radical changes in the policy.

We have had executives in the Street and the Park Department, who gave locations for gas mains in sidewalk in preference to the paved or macadam street, while their successors changed the policy entirely and kept the pipes wholly in the roadway.

Unless some settled policy is in force, it is impossible to intelligently locate the outlets for branch streets when a new main is laid.

Every corporation or municipal department in a growing city is sure to outgrow the capacity of the original pipes and conduits and the locating and laying of reinforcing pipes is a serious problem. The old 14-15 puzzle has a rival in finding a location for such new pipes.

But above all things, the problem of maintaining existing pipes in a safe condition is the most serious one for the gas company and it is not always the last fellow in the street who has the worst of it. Everyone knows that a cast iron pipe that is undermined is liable to settle and either leak or break. This is especially dangerous when a manhole is built so as to enclose or support the pipe, while the adjacent lengths are depending on soft backfilling for support.

The pipes may be so covered or crowded by new structures that it is practically impossible to caulk the joints and we may incur large bills for damage to the electric cables by driving bars and picks, when making necessary repairs.

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From my investigations of conditions existing in several of the larger cities, widely distributed from Maine to Oregon, I find the solution of this problem is often a local one as some of the conditions vary in different cities.

As to the permanent rights of the gas mains in the street, it is conceded with few exceptions that the gas company has few rights that the city is bound to respect and any gas pipes which interfere with the work of the city or State must be changed at the expense of the gas company. In many cities the gas companies can collect damages from contractors on city work who damage their pipes and there is an important exception to this custom in one city where the gas company is recompensed by the city for moving its mains on account of subway construction. In a few cities the gas company is paid actual cost for moving its pipes and occasionally a gas company bills the city for damage to gas pipes due to carelessness only.

In some cities the locations are not assigned or approved by the city, while in others, such assignment or approval is made after plans are submitted by the gas company.

In many cities there is a well-established understanding as to the locations of the sewers, water and gas mains, while the location of the electric conduits is more a matter of chance.

The locations assigned the pipes vary in the different cities. In one very large city, the water main is located in the center of the street, where most often we find the sewer.

In one city the center of the street is given to the gas main. This, to me, seems a most happy condition, unless the street is wide enough to require two lines, or the center of the street is occupied by the street car tracks.

From this location, services can be run to either side without blocking the street, or requiring the pipe to be laid in two sections.

In one important city the mains are laid between curbstone and line of street when practicable.

Most gas men select a location in the roadway near the

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curb line and if there are car tracks, there should be two mains.

The general manager of one gas company says, "Gas mains are given preference over water, sewer and conduit lines, owing to the necessity of obtaining drain for condensation." What a pity other communities are not equally enlightened as to the respect due a gas main!

Philadelphia comes as near to a standard system of locations for pipes, sewers and conduits as any of the largest cities and locations of most of the underground structures are assigned by the Board of Highway Supervisors consisting of:

Director of Public Works (Pres.).
Chief of Electrical Bureau.
Chief of Highway Bureau.
Chief of City Property Bureau.
Chief of Survey Bureau.
Chief of Water Bureau.

Standard locations as follows are generally followed:

Gas 3½ feet from curb.
Telephone 5 feet from curb.
Sewer 7 or 8 feet from curb.
Electric railroad conduit close to either rail.
Water in center of street.

Mr. Forstall states that this plan of standard locations often receives a setback, other than that due to existing structures installed before the plan was inaugurated, owing to the fact that the three city bureaus which install underground structures, lay their own pipes or conduits without consulting the Board of Highway Supervisors, and take any location it deems best for itself. Thus we see that any carefully thought-out system will prove to be a failure if the city departments who are responsible only to themselves ignore its provisions. We could hardly conceive of a corporation being allowed to break up a system in that way.

The city authorities of one very large city have recently attempted to establish a Bureau of Sub-surface Structures,

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designed to locate and map all sub-surface structures, so they will be able to assign proper locations for all structures of all sub-surface companies, which will insure permanence and prevent interference with existing structures. This is the theory, but I am informed that up to the present time about $^1/_7$ of 1 per cent. of the territory has been plotted, so we may confidently hope the grandchildren of the present generation may look forward to enjoy its benefits.

A somewhat similar scheme was tried in Boston about 25 years ago, but after the original sectional plans were made, there was no appropriation to keep them up to date and, of course, they soon became of little value, so now our plans must be compiled by collecting data from all companies and departments known to have pipes in the street.

A gas company with which I was connected was required to file plans annually at City Hall, showing locations of all gas mains laid, but I doubt if they were consulted by the departments for whose benefit they were made, as their draughtsman always came to the gas office to compile their location plans for water pipes and sewers.

It may be practical for some of the more modern cities to start such a system and derive practical benefit from the data on file, but for an older city, where gas pipes have been laid annually since 1824, and its systems of water pipes and sewers are also entitled to the respect due old age, it is not an easy thing to establish on a practical basis, without a large annual expenditure, and for this reason such schemes are apt to come to an untimely end.

The Technical Committee, in calling for a paper on this subject, realized that it would not be practical to recommend a plan for assigning specific locations for the various pipes and structures that could be generally adopted in all cities, but its value would be more to remind the men in charge of street mains of the importance of foresight in determining the proper locations for their pipes. This can be taken up in its most practical form by dealing with the local men who use or control the streets.

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It is fortunate that as a rule the relations existing between these parties are as friendly as can be expected and it is the man who uses tact and consideration for others who succeeds best in the long run.

It is my fortune to be located in a city renowned not for the width or straightness of its streets, and in which congestion describes the existing conditions in its business section as truly as in any city in the country, with perhaps one exception; a city that has been blessed in the past with competing electric light, telephone, telegraph and gas companies, with all that implies.

The most of this paper has been a recital of a local tale of woe, but its usefulness to others will be only as an incentive to do all in their power to prevent such conditions in their own cities.

THE CHAIRMAN: Gentlemen, we have listened to two interesting papers, one by Mr. Simpson and the other by Mr. Gould, and I take pleasure in stating now that the papers are open for discussion. We would be pleased to hear discussion now on the papers presented.

MR. J. D. VON MAUR (St. Louis): I have read Mr. Simpson's paper with a great deal of interest. The exceptional precautions described in his paper are undoubtedly justified by the unusual conditions encountered. It is safe to say that the enormous expenditures and precautions taken by the New York Gas Companies have been justified by experience, or else the expenditure would not have been incurred. Conditions in New York are probably more difficult than in any other city in the world, and it does not necessarily follow that gas companies in other cities would be justified in adopting anything like similar precautions. We should all take heed of the lesson, however, that it pays to build right in the first instance, for conditions in other large cities will gradually approach conditions in New York, and there are already in some of the cities small districts where the very congested state of underground conditions has already been reached.

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Most important of all questions it seems to me is the one relating to the proper location of gas mains. It seems strange that with our industry over 100 years old no solution to this problem has been reached, and while the proceedings of our gas associations are voluminous in other matters, it would be very difficult to find in them any definite recommendation as to what the proper location of gas mains should be. Even if a municipality with the very best of intentions should decide to give the very best locations for our gas mains they would not be able to get any definite advice from any discussions which have ever taken place in our Institute proceedings and where else could they expect to find the very best thought on this question?

In the opinion of the writer there is but one BEST location for a gas main, namely, the space just outside of the curb line. The reasons for this should be obvious. To begin with, gas services are practically run into every building. They must be laid to grade, and owing to their nature must be relaid periodically. Furthermore, they carry a dangerous substance, making it a public interest that they be molested as little as possible.

The water mains should be laid just outside of the gas mains, for while water services are also laid to each house, it is not so necessary that they be laid to grade.

Any location of a gas main which allows conduits to be laid between it and the curb always means interference with the gas services, and frequently renders the main itself inaccessible for running gas services, owing to the elevation of the conduits. Even where there is only one main laid in the street this main should be laid close to the curb on one side, and when the street becomes congested, then a main should be laid on the opposite side, and all services on this side of the street transferred thereto.

In addition to the above precautions, an effort should be made to reduce the number of mains to a minimum, even though it may cost considerably more to replace two smaller

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pipes with one larger one. Had such a policy as the above been followed in years gone by, it is safe to say that a great deal of money and trouble would have been saved. I appreciate, of course, that in the past such a policy was not always possible, owing to the number of companies operating in the large cities, but this condition has been almost entirely eliminated, so that to-day there is no excuse for not following some more logical plan of installing our distribution systems than was done in the past.

In Philadelphia, where the conditions have been almost ideal, and where the location of mains could easily have been selected in the best available space, a distance of some three feet, six inches from the curb was selected. Just why, it is difficult to understand, unless the story is true that this location was selected so that the main could always be found by laying the shovel against the curb and excavating near the handle. As the city grows and the space between the gas main and the curb is filled in with other conduits, the resulting condition will rapidly become worse.

The above remarks could probably have been more appropriately made in connection with Mr. Gould's paper, but the subject has such a vital connection with the question of leaks, and the protection of gas mains, it seems to me entirely appropriate to discuss same in connection with Mr. Simpson's paper. But it is a condition that confronts us and not a theory. Every one will admit that liberal precautions must be taken to prevent accidents, not alone due to the fact that the public is entitled to all of this protection, but also because it is more economical to prevent accidents than to repair the damage after the accidents have taken place, but just what precautions should be taken in each case must be determined by local conditions and past experience. For instance in St. Louis the total number of street leaks on mains, services and street lamps which we were called upon to take care of for 12 months ending July 1st, of this year was —434. Of this number 366 were on services of various

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kinds, and 68 were what are known as main leaks. Of the 366 service leaks, 133 were caused by passing vehicles breaking lamp posts, leaving 233 service leaks, or less than 1 per day for the year. Of the 233 service leaks, 55 were caused by grading machines on streets which were about to be paved. Seventy-six were caused by services rusting out, and 19 were due to leaking fittings. The balance were due to electrolysis, leaking cocks, etc. Of course where the street is entirely overhauled we find services which are eaten out by electrolysis or rusted out from corrosion.

Referring now particularly to the main leaks, they consisted as follows:

(6) 3-inch broken mains,
(24) 4-inch broken mains,
(6) 6-inch broken mains,

or a total of 36 broken mains for the year, the bulk of which were broken in connection with sewer work.

We had—

(3) 6-inch leaking joints,
(8) 12-inch leaking joints,
(4) 10-inch leaking joints,

or a total of 15 leaking joints for the year, every one of which was a lead joint. There was not a single leaking cement joint throughout the entire year.

We had only one leak on a large size main and that consisted of a bar being driven into the top of a 16-inch main by the local Street Railway Company.

The question naturally arises, "Would we be justified in patroling all of our mains daily, as they do in New York, and to a less extent in Philadelphia and Chicago?" We have not had an explosion of any kind in years. Of course we have no assurance that we will not have any in the future, but it is extremely doubtful whether we could anticipate or prevent these explosions by any system of inspection such as has been described by Mr. Simpson.

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It will be noted that the bulk of our leaks have been on services, the total number of our main leaks being very small, namely 36 broken mains and 15 leaking joints for the entire year.

While we, of course, watch all sewer work, grade crossing work, deep foundations for buildings and similar activities on the street, we depend more particularly on our methods of doing our own work, and on maintaining the respect and good will of the various contractors, public utility companies and city officials. If we expect others to respect our property we must, in all fairness, respect the property of others. I can say with absolute truth that we have not knowingly molested a sewer, water pipe or conduit of any kind belonging to either the city or other public utility companies in the past 10 years. This policy has had its effect so that to-day this same policy is being followed by the city and other companies doing underground work. I doubt whether any city can show a less number of street inspectors than the St. Louis Companies. None of us would think of damaging the property of others, and should such damage result accidentally, we do not wait to have this fact found out, but immediately notify the company whose property has been accidentally damaged. I regret to say that this policy was not in vogue prior to 10 years ago, and as a consequence gas pipes and water pipes have been constructed in manholes and sewers, and worst of all, conduits were laid on either side of the gas mains in many instances, bringing about a very undesirable condition which could very easily have been avoided had the suggestions made in this paper been followed from the beginning.

It would seem that the owners of the various public utilities could very easily prevent the damage of one another's property. It is a waste which can and ought to be prevented. When the employees of any company fully understand that the owners will in no wise permit any molestation of other company's property it will not be long before the street work will

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be conducted on the high plane that it ought to be conducted. The owners in their turn ought to know that in the long run this is the most economical policy for all companies to pursue.

The contractors case is a little different, but most contractors will appreciate good treatment. All we ask of a contractor is that he use reasonable precautions in doing his work, and in the event that he is in doubt, or where he accidentally breaks a service pipe, or does other damage, that he immediately call up the gas company, so that advice can be given and repairs promptly made. If an attempt is made to charge a contractor for every minor repair he is very likely to cover up or make temporary repairs to any pipe which he may damage. We have frequently found, in years gone by, pick holes in service pipes which were repaired by winding cloth around the pipe. It would not be very long before we would expend a great amount of money in making these repairs, which could have been avoided if the contractor would have notified us in the first instance, so that the repairs could have been properly made at the time. Where, however, contractors are plainly careless and negligent every effort should be made to punish them, even though it may cost considerable expense to do so. In the case of city work the city officials should have it made plain to them that while apparently the expenses incurred by the public utility company in repairing damage done by city contractors, or where the location of municipal work is selected so as to unnecessarily cause an expense to the companies for the removal or relocation of their underground pipes and conduits, is paid for by the companies, yet in the long run all of this expense is paid for by the consumer. The additional expense comes as an additional cost in supplying gas service, and when rates are determined this expense must necessarily be taken into consideration by those fixing the rate at which gas is to be sold. Thus the entire expense comes back on the consumer.

A further fact should be borne in mind that where public

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work is done in a careless manner, such as the improper filling in of trenches, etc., which allow of a settlement not only vertically but a slight movement of the banks laterally, the result means leaking joints and broken mains both on water pipes as well as on gas pipes. This means an additional expense on the community, aside from the inconvenience of unnecessarily tearing up the street to make the repairs. Our influence should be used with the engineers under whose direction the bulk of municipal and private work is executed, and also with others in authority to see that justice and common sense are used in conducting work on the above lines. We should not stop here, however. Whenever expensive improvements are made in a city street we should see to it that our mains are permanently located in the best possible position that is permitted under the circumstances, and that no more pipes are placed in the streets, or allowed to remain there than those necessary to give ample and sufficient service. What the best location is, in the opinion of the writer, has already been referred to. We do not always but we frequently do have a choice, and have had many choices in the past, but we have overlooked our opportunities.

Where streets are to be paved or reconstructed, care should be taken to see that the mains and services are in proper condition. It would not seem necessary, however, except under exceptional circumstances, to uncover the entire system of pipes. To do so in every case seems to me to be a useless expenditure of money. It should only be done where there are special reasons for so doing.

That it pays to follow along the above lines has been demonstrated in the case of the company with which the writer is connected. With two-thirds the number of services in use as that mentioned for New York City, on page 41, and over 900 miles of mains, and 22,000 street lamps, the entire cost of our street main maintenance for the past 12 months was very small indeed.

Where, owing to construction work of one kind or other,

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the conditions are such as to make possible an accident to our gas mains we simply put in valves at such locations as will place the dangerous district under control. The suggestion is made that it will pay in the matter of making complicated intersections to keep close to the curb around the corners of intersecting streets, and then make the cross-over away from the intersection. In this way we can avoid the mass and net work of manholes which we invariably find at such intersections, and also get away from the complicated intersecting street car curves.

THE CHAIRMAN: For the benefit of those who have come in since we have read the two papers, I want to again say the two papers presented by Mr. Simpson and Mr. Gould are open for discussion. We will take great pleasure in listening to discussion on these papers.

MR. R. C. KELLOGG (Brooklyn): Mr. Gould's paper in dealing with the subject of location by some separate municipal bureau, as to what is in the street, has interested me very much, because in Brooklyn, we have a sub-division there of the Mayor's office known as the division of sub-structures, whose general plan was copied from that employed in Philadelphia. This division has parties in the field all the year round under the charge of a competent chief. They take note of everything in the line of sub-surface structures, sewers, water mains, telephone conduits, electric light conduits, telegraph cable conduits, and the gas main, which data we supply them. It is proposed in the future, when the records of this division become sufficiently valuable, that is, when the entire town has been plotted, which they estimate will take about 5 years more, to charge a certain small fee, practically the cost to the city of doing this work, for information about sub-surface structures, and they will supply that to any corporation desiring to locate such structures of any sort in the City of Brooklyn.

At the present time there has been plotted 17 per cent. of the entire total area in Brooklyn, comprising about 110

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square miles, and they have 25 per cent. of the most congested part of the city plotted.

In reference to Mr. Simpson's paper I would like to say that we use a system of patrolling the entire city. We have 14 men under the head of an experienced expert at all times out on the district, who cover same every day. Their principal object is to investigate conditions where other companies are making excavations contiguous to our property, and if the conditions look dangerous to report immediately to the office by telephone, so that somebody in authority may go out there and investigate that condition and make some arrangements with the other company as to the disposition of the gas mains which are jeopardized by their work. The chief of these men goes over the city on a motor cycle and covers the entire section every day, meeting the men on their rounds and receiving any minor reports of conditions with which they may become familiar.

In reference to blocking of mains referred to in Mr. Vincent's paper, we have found that it is best to use blocking on all sizes of pipe, the reasons for this are that in the conditions of soil peculiar to Brooklyn, the blocking furnishes a better foundation than the bottom of the trench because it can be driven or hammered into the dirt and also because no matter how careful a foreman, may be, he will not always be able to dig a trench bottomed out to a true grade, and by using a block back of each hub it is possible to depress the pipe sufficiently by tamping the block down to a position where the pipe may have the proper fall.

In regard to protection against corrosion, we have found that tar is always the best, as Mr. Jones has brought up. As to electrolysis, we have been trying out a coupling of our own design on service pipes for about 2 years. It is composed of a piece of 3-inch pipe, wrought iron, about 7 inches in length. This is placed in a vertical position upon a board and a coupling of the size of service to be run on one end of a piece of wood is placed inside exactly in the middle. This

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piece of wood is round and also of the same diameter as the service, and on its upper end another coupling is placed so that its top is even with the piece of 3-inch pipe. The outside surface of this coupling is nicked in several places by means of a diamond point and hammer, so as to furnish a bond for the cement grout which is poured into the 3-inch pipe until it is full. The cement is allowed to set for at least 7 days so as to become thoroughly hardened and dry. This device is then placed on the run of a service just after it leaves the main and has been tried out by us for more than 2 years with excellent results. In fact these results were so good that a patent has been obtained.

In regard to machine caulking of cast iron mains: Machine caulking is very little cheaper than hand caulking, but it is much more satisfactory because a better joint is obtained. Men working from 8 to 10 hours a day are bound to get tired during some part of this time and the joints made during this period of fatigue are the ones which will eventually leak, whereas, if you have a machine, which does not get tired, you conserve the energies of your men and get a better joint.

Couplings containing rubber are not to be recommended. They are all right for natural gas but artificial gas goes right through them. They last anywhere from 6 months to 2 or 3 years.

As to service valves, the Building Code of New York City requires them placed on all public buildings of any character whatsoever, and we are making a practice there of putting them on all houses which have 6 families or more.

In regard to overhauling prior to paving, we have records of all our mains, and where a main has been down 3 or 4 years we look over the situation and bar down to see whether the main is in good condition or not, and sometimes uncover 4 or 5 joints, if the bar hole seems to warrant it: If it appears necessary we overhaul the whole line. The services are also overhauled at the same time prior to the city repaving the street or putting down new pavement. We lay nothing

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less than 4-inch pipe, and that is all laid in the outlying sections. In the City of Brooklyn nothing under 6-inch is laid.

Mr. J. A. Frick (Alletown, Pa.): While Mr. Simpson's paper covers the patroling and supervision of operation of quite an extensive nature, it is equally true that it is just as necessary to carry this on a smaller scale in the smaller sized towns. Some years ago I was connected with the Consumers Gas Company of Reading while the city was putting down about 30 miles of house sewers. The city is underlaid with a limestone formation, which made the work extremely difficult. I think we had practically all of the powder experts in the country in town at one time or another, because they found owing to the seams in the limestone, a blast either was not effective at all or else was entirely too effective. We started to patrol to a certain extent. We did not take any extensive precautions until a 6-inch main was broken in 3 places and set on fire and a charge of three and a half sticks of dynamite unexploded lost in the trench. Then we decided it was about time to take some notice. We put on inspectors, and gave each inspector 2 sewer gangs to cover. These inspectors kept in very close touch with the work as it was going on, also as to time of blasting. They arranged between themselves always to have 2 inspectors where their districts touched, meet and be together when the proposed blasting was about to be done. We put in the usual bag holes and took care of the work in that way. In some instances we found it necessary to run temporary mains on the surface, abandoning the old mains entirely and making temporary connections, as was done in this subway work. We found that where the sewer trench was on the opposite side of the street from the main location it did not lessen the danger to any great degree, because where the blasting was done under a service, it usually resulted in the service being pulled from the main and the main broken. We found the quickest way to get around this was to cut the services on either side of the trench and hook up temporary hose connections which could

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be disconnected while the blasting was being done and then immediately put back. The consumers were not out of gas over 10 or 15 minutes at a time. This work lasted for, I should say about a year and a half, and all of us gained a great deal of valuable experience in that time, and we were particularly fortunate to be able to go through that period without any serious damages of any kind. It merely illustrates that if things are properly handled and precautions taken, which are not necessarily very expensive, you can obviate probably a good deal of greater expense later.

MR. W. O. LAMSON, JR. (West Chester, Pa.): In reference to Mr. Forstall's paper, the question of taxation for inspection of mains brings home to us a subject of very vital importance, in this way, that if the gas companies, particularly in the smaller places, took some precautions to inspect their mains and inspect their work, the taxation would less likely be imposed. I do not agree with Mr. Forstall when he says that it is always done as a means of revenue, because it is incumbent on the borough or the city to show some inspection for their charge, but if the borough or the city is already charging for a permit to open a trench, they cannot, of course, collect the tax without showing they have spent time and money to make the adequate inspection to cover the charge. However, if the companies can show a reasonable inspection of their work, of both underground pipes and surface work, I do not think it would be as likely to have this tax imposed. I believe it could be obviated by introducing some system of inspection

THE CHAIRMAN: Anything further, gentlemen?

MR. H. B. ANDERSON (Philadelphia): The following table shows the results obtained by the use of our special line walker in a section of the City District in Philadelphia.

The line walker was used with the intention of discovering the existence of gas leaks before they come to the attention of any of the public, thereby making it possible to stop the leak before any damage is done or any possibility of a claim can arise. This line walker patrols his route every day in day-

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time, during weather when we decide that there is a possibility of leaks due to frost. We have followed this procedure for the past 4 winters and the results for these periods (shown as a total) will speak for themselves.

I think we may assume in about 50 per cent. of the cases, where our line walker reported a leak, which on investigation proved to be a service leak or a broken main, that unless the line walker had discovered it, there would have been every probability of the escaping gas entering a house and a great probability of someone in the house being affected.

Leaks found on	Broken mains	Main joints	House services	Total
Line walker's reports	34	68	27	129
All other reports	33	32	47	112
Total	67	100	74	241
Per cent. reported by line walker	52	68	36	53

MR. WALTON FORSTALL (Philadelphia): It would seem that the question of the intelligent apportioning of the space in the streets of our large cities is well worth the consideration of the various Public Service Commissions. My thought in this regard is that often a public service company does not get the hearing from the city authorities in a mattter of this kind that would be accorded to a representative of a Public Service Commission. I am not prepared to state that a Commission should be given mandatory power in this regard, because I am a great believer in "Home Rule" for cities. There is every reason to believe that results could be accomplished through suggestion. Taking Philadelphia, for instance: If the New Pennsylvania Public Service Commission should call the attention of the Philadelphia Board of Highway Supervisors to the one fault now existing in its present allotment of street space, namely, that the city structures—water pipe, sewers and electrical conduits—are located by the respective bureaus, and not by the Board of Highway Supervisors, the Highway Supervisors would be quite apt to insist that the city structures be subjected to the same loca-

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tion rules applying to the structures of the Public Service Commissions.

In other states, the Public Service Commissions should, as time and opportunity offered, persuade their large cities to adopt some such method as that used by Philadelphia. The subject is of great importance, because there is overwhelming evidence that practically the only reason for leaks in mains laid in recent years, is because of their undermining by other structures. As in a majority of cases, the gas company is unable to prevent the location of other structures in positions designated by the city, it is clearly the duty of the latter to recognize its responsibility in this regard, and to devise a proper system for the allocation of underground space. After such a system has been in operation for some time, there will be less chance than is now the case for a city like Detroit to raise the question of proper specifications for cast iron, where the city authorities had wrongly ascribed many street leaks of January and February, 1912, to weak material, instead of to the influence of abnormal weather upon mains whose support had been weakened by undermining. Our Philadelphia experience during this extreme weather is conclusive evidence of the practical immunity from leaks of modern cast iron pipe on good foundations. We had 302 breaks in 550 miles of mains laid by the city, and only 19 breaks in practically the same mileage laid by this company. One of the principal reasons for the great number of breaks in the city mains was that they had been laid on poorly filled ground. Had the city insisted on a proper compacting of the fill, or given the mains a secure foundation in any other way, both the company and the citizens would have been relieved from a good many disagreeable experiences last year. Of course, all of these experiences, were, from the newspaper standpoint, chargeable to the present company.

In view of the above facts, I think that all of us should do what we can to impress upon our city authorities the vital importance of allowing our structures the undisturbed posses-

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sion of as much sub-surface territory as is required for firm foundation. An illustration of one of the results of such undisturbed possession is, I believe, afforded by the fact that in Philadelphia we have for years been practically free from any explosions in manholes or conduits, caused by illuminating gas.

MR. E. C. JONES (San Francisco): Any Eastern gas company which is allotted a location for its mains may consider itself extremely fortunate in these days when gas companies are regulated by municipalities or by State Commissions. There should be protection as well as regulation, but unfortunately our business is in a transitory stage and we are not quite in a position to ask or demand the protection of our mains. It seems in our Western cities to-day as though a franchise meant nothing, although you pay taxes on it. A short time ago the City of San Francisco decided to put in a salt water fire system for obvious reasons, and in laying the pipes through the streets of San Francisco they required us to raise, lower and entirely remove gas mains without compensation. I remember years ago a water company in California having all its cast iron specials made with wings cast on the bells in order to keep its neighbors at least 18 inches away from it. Those good old days have gone by, and I think that we as members of the Institute should exert ourselves to bring pressure to bear on Commissions and regulating bodies to give us protection to our mains. We are certainly large tax payers in any community, and as tax payers I believe we have our rights.

MR. A. M. BARNES: I should like to ask Mr. Forstall a few questions in regard to the 2 papers that he read. If I understood him correctly, in some towns or cities in Pennsylvania, they have the police patrol the street main system of the gas company and charge that up to the gas companies as an expense. Am I right? Did I understand you correctly?

MR. WALTON FORSTALL: Mr. Chairman, as I understand the situation in at least 2 if not more cities of Pennsylvania, it has been held that the city has a right, in the exercise of its

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police power, to charge so much per mile per year for the inspection of the gas mains by the police force.

MR. A. M. BARNES: That is what I understood you to say, and I was wondering how far that could be set up in defence by the company in case of their being sued for damages. If the city undertakes to patrol the gas system and notify the gas company of a leak, is not the gas company entitled to wait until they hear from the city that a leak exists, and in that case would they be likely to be held responsible by the courts of Pennsylvania for any damages resulting? If that would relieve the company of a charge of neglect, it seems to me that it might be a pretty good way to handle the matter. Let the city patrol the system and pay that expense rather than pay damages.

Another question I should like to ask: He mentioned 302 leaks in the mains located by the City of Philadelphia when the city had charge of the gas supply, and only 19 in pipes of similar length under the new management. It might be of interest to know how long the pipes had been in the ground, and whether or not that had any effect or bearing on the question.

I should like to say to Mr. Jones of California that we in the East do not enjoy any greater facilities or powers as regards the location of our pipes at the request of the cities at any time and without charge. We are given the location, but if the city comes along with a sewer or the water board with a new main, we have to get out of the way. They give us another location, but we have to change, at our expense.

MR. WALTON FORSTALL: Mr. Chairman, answering Mr. Barnes, I don't know that the courts have ever decided on the point he raised. I think the average gas company would be rather averse to a situation where, if an accident occurred, they would go into court and say, all the responsibility for our gas mains has been taken away from us and you must look to the city. I think that public opinion would not stand back of the gas company, although, of course it should; but I will say

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this, that I know one town in Pennsylvania in which a very enterprising superintendent told the City Council, "If you pass this ordinance and charge our company for inspection we will hold you responsible for all the accidents," and the City Council backed down. That is the way he got out of it. As to the age of the pipes, of course, the pipes that were laid by the City of Philadelphia were very much older and smaller than the pipes we laid, but I have seen no evidence in the 150 miles of mains we have taken out that the pipes have been sufficiently corroded to be weakened. I think the 2 and 3-inch mains are just as strong to-day as they were when they were first laid.

MR. J. D. VON MAUR (St. Louis): In answer to Mr. Barnes's question, I think the answer is very clear. We could simply hold they were acting as the gas company's agent.

MR. M. H. SPEAR (Flushing, N. Y.): Speaking for a small company having about 100 miles of mains, I have never seen the necessity of having a constant patrol system. If the city lays a sewer or water main and our gas main is in the way, we have to remove it at our expense. In private contracts such as telephone or electric light conduits they have to pay us for removing our main. In either case as soon as they expose our main we put an inspector on the job to see that our mains our properly taken care of.

THE CHAIRMAN: If it meets with your approval and there is no further discussion on the papers, I will ask Mr. Forstall to close the discussion on Mr. Simpson's paper which he presented.

MR. WALTON FORSTALL: It is pretty hard to close a discussion on another man's paper, and I do not believe there is much to be said. Mr. Simpson was describing conditions in New York. I do not think Mr. Simpson in any way wanted to say that other people should do what New York does. I think Mr. Simpson and I both agree that the small company should do whatever is necessary, and that may mean nothing

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in some cases. It does not necessarily mean a continuous system of inspection.

THE CHAIRMAN: Now, we will listen to Mr. Gould.

MR. J. A. GOULD (Boston): I agree so thoroughly with what has been said, that further remarks are unnecessary at this time, and I think my unabstracted paper covers some of the points mentioned by the speakers. About this inspection business, I do not think it necessary for a gas company to make a daily patrol of all the streets in which its mains are laid. I think it is an unnecessary waste of time. In our city we receive a daily report from the permit office at City Hall of all permits issued for street openings, and these are given to our local inspectors covering the several districts. In this way our men are in touch with any operation that may affect the safety of our pipe, and their time is not wasted in patrolling streets where we have no trouble and are not liable to have any. We have special inspectors assigned to special jobs. At present the 3 subways now building are each covered by a day and a night inspector. I believe in concentrating inspection when there is something special to inspect and not waste energy in looking for trouble where none is probable. Neither do I believe it necessary to uncover all your mains and services for examination when a street is to be repaved. A careful barring should be sufficient unless we wish to trace out complications in the piping, due to duplicates originally laid by competing companies. I think this scheme of Mr. von Maur's for getting around congested corners is a feasible one, and in fact has to be done in a few cases in our city.

MR. M. H. SPEAR: May I ask Mr. von Maur if that scheme of his does not interfere with the catch basins on the corners?

MR. J. D. VON MAUR: Sometimes it does and sometimes it does not, but where we have complicated intersections to deal with it will be found that the method described is by far the lesser of two evils.

THE CHAIRMAN: We have just learned that Mr. Whit-

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taker, who is to present the next paper, is busy engaged in a discussion in the other room, section A., so if it is agreeable to Mr. P. H. Millar we will ask him to present the paper entitled, "A Portable Electric Photometrical Standard, Its Construction and Use," prepared by Dr. C. H. Sharp and Mr. A. H. Schaaf.

Mr. P. H. Millar (New York City) then read paper on above subject.

A PORTABLE ELECTRIC PHOTOMETRICAL STANDARD, ITS CONSTRUCTION AND USE.

Abstract.—In spite of the difficulties inherent in the use of flame standards, they have been used exclusively for gas photometry because they are affected by atmospheric conditions, in a manner similar to the gas. This is not the case with electric standards. An electric standard, however, has the advantage of immediately assuming its designated candle-power without waste of time in preliminary work. It is advisable, however, to allow 5 minutes for heating and it is, moreover, cheaper than either candles or pentane, and errors due to the standard itself are practically eliminated It is proposed here to show how difficulties caused by variations of humidity in connection with the electric lamp can be eliminated.

The standard described is a tungsten lamp of suitable candle-power supplied by a storage battery. By using low voltage, the number of coils is reduced to a minimum. The apparatus depends upon the important quality of tungsten to change its electrical resistance rapidly with change in current, so that if a lamp forms one arm of a Wheatstone bridge and the bridge is in balance when the lamp is giving its exact candle-power, the only adjustment necessary to bring the lamp to its standard condition is to move the rheostat until the deflection of the galvanometer is zero. The whole operation requires but a moment's time and can be performed by a person entirely unskilled in instrument work.

The lamp is operated at 4 volts and 1 ampere, and at 2 watts per candle. The life at this low efficiency is practically indefinite, and hence variability of candle-power with age is almost negligible. The measuring apparatus consists of 2 rheostats for coarse and fine adjustments respectively. The battery is a 6-volt portable storage battery with capacity enough to supply the standard for 40 hours. A telephone receiver in series with a current interrupter may be used instead of the galvanometer.

To introduce the atmospheric changes, it has been found very con-

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venient to change the value of the lamp, while in actuality the candle-power of the lamp remains constant.

Since the electric lamp is not affected by changes in barometric pressure the value of the lamp for a 2 candle-power unit would be:

$$C.\ P. = 2\ (1 + 0.00567\ (e - 8)\ ;$$

where e equals the number of liters of water vapor present.

A number of tests was made to determine the reliability of the standard as compared with the pentane lamp, which showed an average disagreement of ⅓ per cent., with a maximum deviation of 1.3 per cent.

Part I.

BY CLAYTON H. SHARP.

The use of electric standards of candle-power has ordinarily been associated with the installation of apparatus which is very expensive to purchase and very difficult for any but a man trained in electrical laboratory work to use. It has usually been considered that a good sized storage battery of 60 or 70 cells is required for the operation of an electric standard lamp, that one or more instruments of precision are needed for the control of the electrical conditions, that charging arrangements must be provided, wires must be run, rheostats installed, and in short an extensive fixed equipment supplied. These considerations have undoubtedly restricted the use of electrical standards of light in many cases. Especially to those operating gas plants, the above objections to the electric standards would in most cases prohibit their use, even if gas engineers were favorably disposed toward them. As a matter of fact, electric standards have been considered as practically inapplicable to the photometry of gas for the reason that the electrical standard is not subject to changes in its candle-power due to atmospheric conditions, as are the flame standards and the gas which is being photometered. The photometry of gas therefore has been universally carried out by the use of flame standards: candles, and more recently, the 10 candle-power pentane lamp.

Much has been written of the unreliability of candles in photometry. Many gas men do not agree with a good many

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such statements for the very good reason that their long experience in the use of candles has developed in them such an extraordinary degree of skill that they are able to get surprisingly good results. It cannot be denied, however, that both candles and the pentane lamp are in certain respects greatly at a disadvantage by comparison with electric standards. An electric standard can be brought to its designated candle-power almost instantly after throwing a switch, and this can be done with the simplest of adjustments. The use of either candles or pentane lamp, on the other hand, involves wasting a great deal of time in preliminary work, and a determination using candles or the pentane lamp, is a much more lengthy affair than one where an electric standard is used. Moreover, the expense of candles and of pentane lamps, when they are used continuously, is a considerable item in the day's work, whereas the expense of operating an electric standard is almost negligible. The accuracy and reproducibility of the results in the case of the electric standard are so much superior to the corresponding qualities in the candles and pentane lamp, that it is difficult to make a comparison.

The proper use of an electric standard means that errors due to the standard itself are practically eliminated, whereas with flame standards there is always the disturbing doubt as to whether the standard might not have been for some reason slightly abnormal in its luminous intensity. The real arguments against the electric standard are that its first cost is high, its operation not simple and the fact that it is uninfluenced by atmospheric conditions, as the flame standard is. Apart from these considerations a comparison of electric and flame standards shows all the advantages to be on the side of the electric standard. It is proposed here to show how these remaining difficulties with the electric standard as applied to gas photometry can be obviated.

Taking first the non-variability with atmospheric conditions. It is this most valuable characteristic of the electric standard which has enabled photometrists to determine the variability of flame standards with atmospheric conditions. The chief

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variability is due to the amount of water vapor contained in the air. By comparison with electric standards it has been shown that the light of the pentane lamp varies by approximately 0.6 per cent. per liter of water vapor per cubic meter of dry air, going above or below 8 liters per cubic meter as the standard condition. The lamp varies also with the barometric height, but this variation is for any given locality a rather small one. It varies also with the amount of carbon dioxide in the air, but this variation can be eliminated by suitable ventilation of the photometer room. If a gas flame is photometered against both an electric standard and a pentane lamp in an atmosphere containing 8 liters of water per cubic meter of dry air, the results of both the photometric operations should agree. If the vapor content of the air is increased, the candle-power of both the pentane lamp and of the gas will decrease in approximately the same ratio. Therefore the pentane lamp will show the gas to have the same candle-power as if the measurements were carried out under the standard condition of 8 liters per cubic meter. If, however, the electric standard is used when the vapor content is higher, the candle-power of the gas is shown to be lower. Suppose, however, that the amount of water vapor in the air is determined at the time the measurement is made with the electric standard (and this determination is a very simple one to make), then the vapor corrections can be applied to the electric standard itself and this will reduce its indications to the indications of a pentane lamp under those conditions. That is, suppose the amount of water vapor is such as to diminish the candle-power of the pentane lamp and of the gas by 2 per cent. Then if the candle-power of the gas is taken against the electric standard, the measured candle-power needs to be increased by 2 per cent. to give the true candle-power of the gas as measured against the pentane lamp. By an observation of the dry and wet bulb thermometers, the amount of water vapor is readily determined, and this correction can be obtained without any difficulty. Therefore, as far as the humidity correction is concerned, the electric standard can be used in the

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photometry of gas to give the same results that the pentane lamp would give under any and all atmospheric conditions.

It remains to describe an apparatus which has recently been constructed for use in gas works, which obviates the conventional difficulties of the electric standard. The apparatus is

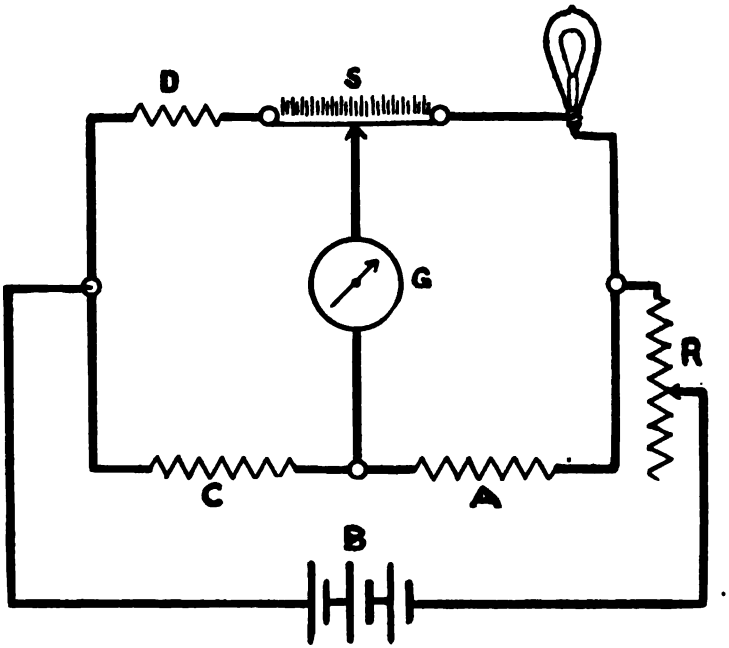

Fig. 1.

founded on the availability at the present time of tungsten lamps of suitable candle-power and of low voltage. By using a low voltage lamp, the number of cells required to furnish the current is reduced to a minimum. The apparatus depends further upon the important quality of tungsten to change its electrical resistance very rapidly with the change in the current passing through the filament. Therefore if a lamp is made one arm of a Wheatstone bridge, and the bridge is so adjusted that it is in balance when the lamp is giving its exact candle-power, the only adjustment necessary to bring the lamp to a

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standard condition is to move the rheostat until the deflection of a galvanometer is reduced to zero. This is an operation so simple that it can be performed even by any laborer. A diagram showing the electrical connections is shown in Fig. 1. The battery B delivers current through the adjustable rheostat R to the Wheatstone bridge arrangement, consisting of the fixed resistance A, C and D, of the lamp L, and of the short slide wire S. The galvanometer G is connected from the junction of A and C to a sliding contact S. In calibrating the standard, the lamp is placed on the photometer bar and the current is adjusted by R until it gives exactly the required 2 candle-power. The contact of the galvanometer wire on S is then moved to such a point that the galvanometer deflection is zero, and the point on the slide wire is noted on a divided scale to which the slide wire is attached. If it is desired to standardize more than one lamp, a separate point on the slide wire is determined for each lamp. A lamp is then brought to its standard candle-power by placing the contact on the slide wire at the proper point and by adjusting the current until the galvanometer deflection becomes zero. This operation is one which requires only a moment's time. If the galvanometer has a suitable sensibility, it is not necessary that the zero adjustment should be made with any very high degree of precision. Therefore it is an operation which a person entirely unskilled in instrument work can carry out successfully.

The lamp used is of tungsten filament and of such a rating that when giving 2 candle-power its color is the same as the color of a gas flame. Therefore difficulties in photometry due to color differences are entirely eliminated.

The lamp is operated at 4 volts with 1 ampere of current, and therefore at 2 watts per candle. The life of a tungsten at this low operating efficiency is almost indefinite. Hence variability in candle-power with age is very little to be feared. The lamp is a special one, having no supporting anchors to disturb thermal conditions. The bulb is of small size and the base is the regular Edison screw base.

The measuring apparatus is mounted on a wooden base and

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consists of 2 rheostats, one for the coarse adjustment and one for the fine adjustment; of the resistance coils, which are enclosed in a box; and of a pointer galvanometer. The battery is a 6-volt portable storage battery, such as is used for lighting and ignition purposes on automobiles. It is readily carried to any required location for charging. Its capacity is 40 ampere-hours; that is, when operating at full capacity, one

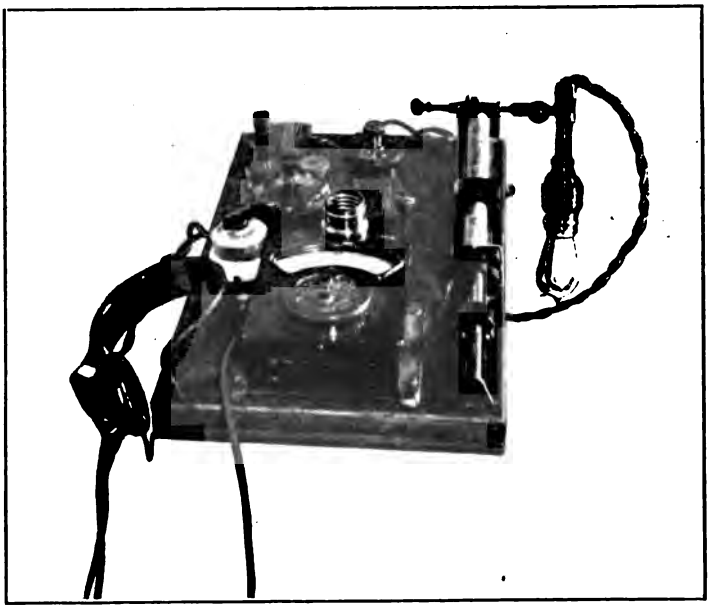

Fig. 2.

charge should serve to burn the standard lamp for 40 hours. Batteries of this character offer no difficulties in maintenance or use and require no special installation facilities. Connection to the battery is made from an ordinary flexible lamp cord, and the battery itself is placed underneath the table. Instead of a storage battery, a battery of dry cells might be used.

The arrangement of the measuring parts is shown more

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clearly in Fig. 2, in which the box covering the coils and keys has been removed. In this figure the slide wire S of Fig. 1 is wrapped around the circular disc at the top of the box. The galvanometer contact to this wire is carried on an arm which can be rotated about the disc and can be clamped in position by means of the thumb-screw; all as shown. The disc is graduated in degrees. The resistance coils A, C and D which are wound of manganin wire of zero temperature coefficient and carefully seasoned, are affixed to flat supports and are seen in the diagram. The galvanometer key is of the circular pattern and has its knob projecting above the box cover.

The apparatus described, being somewhat of an experimental nature, was equipped with two methods of detecting the balance of the bridge. One of these is the galvanometer to which reference has already been made. The other is a simple telephone receiver which is placed in series with a current interrupter. The telephone receiver is placed to the ear and the interrupter, which is seen in Fig. 2 just above the galvanometer key, is rotated. If the bridge is out of balance, a faint ticking is heard in the receiver, which ceases entirely when balance has been obtained. In practice it has been found that the telephone receiver is a sufficiently sensitive substitute for the galvanometer, so that the standard can be set with all required accuracy. It suffers from the disadvantage, however, that it is impossible to tell by the sound whether the current is too large or too small. This difficulty disappears with a little practice in the use of the apparatus, whereby the operator finds at about what point the rheostat should be set to produce proper conditions. Another disadvantage is that the sound may be difficult to hear in a noisy place. The only excuse for the use of a telephone receiver is that it is considerably less expensive than the galvanometer, and its use cheapens the cost of the equipment. Using the galvanometer, deflection to the right or to the left shows whether the current is too large or too small. The key of the galvanometer is so arranged that when depressed part way, a resistance is placed in series with the galvanometer, so that the deflections are not too great or too

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violent. When it has been shown that the adjustment of the bridge is nearly right, the key may be depressed all the way down and this resistance cut out, whereby the full sensibility of the galvanometer is realized. The sensibility is that a deflection of 10 scale divisions correspond to a change in candle-power of 1.6 per cent. Since it is very easy to adjust to within a single scale division, the accuracy of the setting is much greater than the photometric accuracy.

This set was supplied with four standard lamps and has been used by a gas company in the hourly control of its output. There being four lamps, it is possible to check one against the other, and thus to detect any variation on the part of an individual lamp. As to the results obtained in the practical use of the apparatus, the gas engineer is better qualified than anyone else to write. The usefulness of this standard in checking portable photometers is obvious.

Part II.

BY A. H. SCHAAF.

Considerable difficulty has been encountered by gas engineers in deciding on a universal gas standard and thus far they have failed to arrive at any definite conclusion. This is undoubtedly due to the fact that the present flame standards lack accuracy and reproducibility, or else are too sensitive to draughts and vibrations. It is generally known that the so-called standard candles are in error by about 5 per cent. (average), and that they do not fulfil any part of the old specifications of the London Gas Referees. Since the adoption of the pentane lamp in 1898, candles have been sold entirely on the merits of the manufacturer. This may, therefore, account for some of the error. The development of the pentane lamp has undoubtedly been a great stride in the way of a gas standard, but it is not entirely satisfactory as it is too sensitive to draughts and vibrations, and the cost of maintenance too high for a works control standard.

Flame standards have been used exclusively for the photometry of gas, due to the fact that they are affected by the

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atmospheric humidity, and as the electric lamp is not so affected it has been practically abandoned for this purpose. There is no reason, however, why the electric lamp when corrected should not give results that are more accurate and consistent than those obtained by the use of flame standards.

Photograph No. 1.

By correcting for humidity as will be described in this paper we have without a doubt a standard that has proven itself a worthy competitor of flame standards.

The electric standard shown in photograph No. 1 is very

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compact and can readily be mounted on any gas photometer. This instrument does not require the attention of two observers, as the current when adjusted carefully will remain so for the 10 minutes of the test. It is advisable, however, to

Photograph No. 2.

check the current after each reading as slight changes have been observed when the battery charge is low. This standard was designed by Dr. C. H. Sharp of the Electrical Testing Laboratories.

Photograph No. 2 shows the electric standard mounted.

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The Humidity Correction.

The humidity correction has been based on the formula recommended by the Bureau of Standards for the correction of the pentane lamp:

$$I = I_n\ (1 - 0.00567\ (e - 8) + 0.0006\ (b - 760)\ ).$$

Where I is the measured candle-power in international candles under given atmospheric conditions; I_n is the value of the lamp under standard conditions, that is, 8 liters of water vapor per cubic meter of dry air and a barometric pressure of 760 millimeters; e is the number of liters of water vapor and b is the barometric pressure in millimeters. In using the lamp uncorrected for humidity the formula becomes:

$$I = I_n\ (1 + 0.0006\ (b - 760)\ ).$$

In order to have the results of the electric lamp agree with those of the pentane the result must be changed 0.567 per cent. for each liter of water vapor above or below 8. It has been found very convenient to consider the value of the electric lamp to vary rather than to make an additional correction at the end of the test. Example: If the readings of the hygrometer are 15° C. (wet bulb), 20° C. (dry bulb), and a barometer of 765 millimeters.

NOTE.—Wet and dry bulb readings were obtained by means of an ordinary sling hygrometer. From Table 140 of the Smithsonian Physical Tables, the vapor pressure for the given temperatures of the wet and dry bulbs is 10.15 millimeters. The barometric correction as given on the top of Table 140 may be omitted as it does not affect the result sufficiently to warrant correction. For the above vapor pressure we would obtain $\frac{10.15}{760 - 10.15} \times 1{,}000 = 13.54$ liters of water vapor per cubic meter of dry air. Therefore, the electric lamp which normally has a value of 2 candle-power would have under the above conditions a value of: $(13.5 - 8) \times 0.567 = 3.30$ per $(= 0.6)$ cent. change; $2\ (1 + 0.033) = 2.066$ candle-power.

By constructing a curve sheet as shown by photograph num-

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TABLE 140. 155

PRESSURE OF AQUEOUS VAPOR IN THE ATMOSPHERE.

This table gives the value of pressure corresponding to various values of the difference $t - t_1$ between the readings of dry and wet thermometers, and the temperature t_1 of the wet thermometer. The [illegible] given in [illegible] degrees above [illegible] calculated for [illegible] top of the column.*

t_1	$t-t_1=0$	2	4	6	8	10	12	14	16	18	20	Difference per $t-t_1$
Corrections for B per excess metre †		.013	.026	.040	.053	.066	.079	.092	.106	.119	.132	
−10	1.06	0.91										0.100
−9	2.14	1.11	0.14									0.100
−8	2.33	1.33	0.33									0.100
−7	2.53	1.53	0.53									0.100
−6	2.76	1.76	0.76									0.100
−5	3.01	2.01	1.00									0.100
−4	3.28	2.28	1.27	0.27								0.100
−3	3.57	2.57	1.56	0.56								0.100
−2	3.88	2.88	1.87	0.87								0.100
−1	4.22	3.22	2.21	1.21	0.21							0.100
0	4.60	3.60	2.59	1.59	0.59							0.100
1	4.94	3.93	2.92	1.92	0.92							0.100
2	5.31	4.29	3.29	2.28	1.28	0.27						0.100
3	5.71	4.68	3.68	2.67	1.66	0.66						0.101
4	6.10	5.09	4.09	3.08	2.07	1.06	0.05					0.101
5	6.53	5.51	4.51	3.50	2.49	1.48	0.48					0.101
6	7.00	5.99	4.98	3.97	2.96	1.95	0.94					0.101
7	7.49	6.48	5.47	4.45	3.44	2.43	1.42	0.41				0.101
8	8.02	7.01	5.99	4.98	3.97	2.96	1.94	0.93				0.101
9	8.57	7.56	6.54	5.53	4.51	3.50	2.49	1.48	0.46			0.101
10	9.17	8.16	7.14	6.12	5.11	4.09	3.08	2.07	1.06	0.05		0.101
11	9.79	8.77	7.76	6.74	5.73	4.71	3.69	2.68	1.69	0.04		0.102
12	10.46	9.44	8.43	7.41	6.39	5.37	4.36	3.34	2.32	1.30	0.28	0.102
13	11.16	10.14	9.12	8.10	7.09	6.07	5.05	4.03	3.01	1.99	0.97	0.102
14	11.91	10.89	9.87	8.85	7.83	6.81	5.79	4.77	3.71	2.69	1.67	0.102
15	12.70	11.68	10.66	9.64	8.62	7.60	6.58	5.56	4.54	3.52	2.50	0.102
16	13.54	12.52	11.50	10.47	9.45	8.43	7.41	6.39	5.37	4.35	3.33	0.102
17	14.42	13.40	12.37	11.35	10.33	9.31	8.28	7.26	6.24	5.22	4.20	0.102
18	15.36	14.34	13.31	12.29	11.26	10.24	9.21	8.19	7.17	6.15	5.13	0.102
19	16.35	15.33	14.30	13.27	12.25	11.22	10.20	9.17	8.15	7.13	6.11	0.102
20	17.30	16.37	15.34	14.31	13.28	12.26	11.23	10.21	9.18	8.15	7.12	0.103
21	18.50	17.47	16.45	15.42	14.39	13.39	12.33	11.31	10.28	9.25	8.22	0.103
22	19.69	18.63	17.60	16.57	15.54	14.51	13.48	12.46	11.43	10.40	9.37	0.103
23	20.89	19.86	18.83	17.80	16.77	15.74	14.71	13.68	12.66	11.63	10.60	0.103
24	22.18	21.15	20.12	19.09	18.05	17.02	15.99	14.96	13.94	12.91	11.88	0.103
25	23.55	22.52	21.49	20.45	19.43	18.39	17.36	16.33	15.30	14.27	13.24	0.103
26	24.99	23.96	22.92	21.89	20.86	19.82	18.79	17.76	16.73	15.70	14.67	0.103
27	26.51	25.48	24.44	23.40	22.37	21.34	20.30	19.27	18.24	17.21	16.18	0.103
28	28.10	27.07	26.03	24.99	23.96	22.92	21.89	20.85	19.82	18.79	17.76	0.103
29	29.78	28.75	27.71	26.67	25.63	24.59	23.56	22.52	21.49	20.46	19.43	0.103
30	31.55	30.51	29.47	28.43	27.40	26.36	25.32	24.29	23.25	22.22	21.18	0.104
31	33.41	32.37	31.33	30.29	29.25	28.22	27.18	26.14	25.10	24.07	23.03	0.104
32	35.36	34.32	33.28	32.24	31.21	30.17	29.13	28.09	27.05	26.01	24.97	0.104
33	37.41	36.37	35.33	34.29	33.25	32.22	31.18	30.14	29.10	28.06	27.02	0.104
34	39.57	38.53	37.48	36.44	35.40	34.36	33.32	32.28	31.24	30.20	29.16	0.104
35	41.83	40.79	39.74	38.70	37.66	36.62	35.68	34.64	33.60	32.56	31.52	0.104
36	44.20	43.16	42.11	41.07	40.03	38.99	37.95	36.90	35.86	34.82	33.78	0.104
37	46.69	45.65	44.60	43.56	42.52	41.48	40.44	39.39	38.35	37.31	36.27	0.104
38	49.30	48.26	47.21	46.17	45.13	44.08	43.04	41.99	40.95	39.91	38.87	0.104
39	52.04	51.00	49.95	48.91	47.86	46.82	45.77	44.73	43.78	42.74	41.69	0.105

Example.

$t - t_1 = 7.2$

$t_1 = 10.0$

$B = 74.5$

Tabular number $= 6.12 - 6 \times 101 = 5.61$

Correction for $B = 1.5 \times .048 \ldots = .07$

Hence we get $p \ldots = 5.58$

* The table was calculated from the formula $p = p_1 - 0.00066\,B\,(t - t_1)\,(1 + 0.00115\,t_1)$ (Ferrel, Annual Report U. S. Chief Signal Officer, 1886, App. 24).

† When B is less than 76 the correction is to be added, and when B is greater than 76 it is to be subtracted.

Photograph No. 3.

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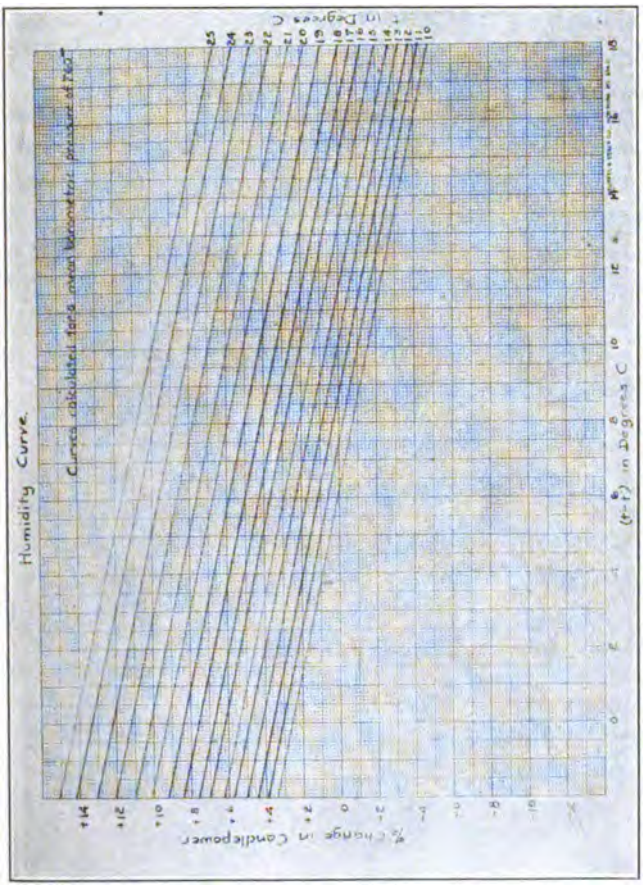
ber 4, considerable calculating will be avoided and the percentage change for the electric lamp can be determined immediately from the readings of the wet and dry bulb thermometers.



Photograph No. 4. Humidity Curve.

Using the preceding values of $t_1 = 15°$ C. and $t = 20°$ C., $(t - t_1) = 5$. On the right of the curve sheet appears the temperature of the wet bulb, and at the bottom the values for

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$(t - t_1)$. Now, using $(t - t_1 = 5$ and going vertically upward to the wet bulb line 15 and then going over horizontally to the left the per cent. change in candle-power is obtained, which is equal to, in this case, 3.3 per cent., the same as the calculated value.

The humidity curves were calculated for a mean barometer of 760 millimeters. At places where the mean barometer is different the same method may be employed.

From the following comparisons the efficiency of the standard may be judged. The lamps used in the electrical standard were standardized by the Electrical Testing Laboratories, and the pentane lamp was standardized by the Bureau of Standards. The comparisons of Set 1 were made by the author, and these tests include a large variation in atmospheric humidity.

SET 1.

The comparisons below were made by the substitution method:

	Pentane	Electric standard
	24.48	24.32
	22.63	22.61
	22.93	23.11
	22.40	22.40
	23.06	22.80
	23.98	24.29
Average,	23.25	23.26

SET 2.

The following tests were made on the same gas with two different photometers:

	Pentane	Electric standard
	23.94	23.10
	24.23	23.33
	23.84	24.11
	23.65	23.04
	22.65	23.50
	23.02	24.45
Average,	23.56	23.59

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	22.80	22.72
	23.18	22.86
Average,	22.99	22.79
	22.14	23.48
	23.38	22.63
	23.19	23.09
	23.45	23.90
	22.51	23.97
	23.21	23.19
Average,	22.98	23.38

SET 3.

The following comparisons are those with standard candles:

	Candles	Electric standard
	23.07	22.81
	22.74	23.46
	23.32	24.01
	24.72	24.79
	23.61	23.72
	23.14	23.54
Average,	23.43	23.72
	24.44	24.07
	22.61	23.12
	22.00	22.14
	23.11	23.16
	22.86	22.64
	22.04	22.53
Average,	22.84	22.94

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	22.41	22.46
	22.63	23.01
	23.25	22.51
	22.84	22.94
	22.93	22.53
	22.74	23.01
Average,	22.80	22.74

NOTE.—These comparisons represent tests selected at random from 3 or 4 months testing and show the performance of the electric standard as compared with the open flames. Comparisons of Set 2 were taken at three different works by the works chemists, the individual tests being taken on different days. In Set 3, the first two averages are those of two consecutive months, the individual tests being taken on different days. The third average represents similar comparisons at another works, as before the individual tests being taken on different days.

Conclusions.—The electric standard possesses many advantages.

First, its cost is about 2 cents per day, including depreciation, which is very low when compared with candles or the pentane lamp.

Second, it is easily operated and no time is lost in heating up as is the case with candles or the pentane lamp. The electric lamp can be kept burning very low so the coils in the bridge will be heated and ready for test at all times.

Third, it cannot be thrown out of adjustment when handled properly. The lamps can be restandardized when so desired and in burning a 1¼ watt tungsten lamp at a gas color, which is about 3 watts per candle-power, there is very little chance for the lamp changing.

If this standard would be universally adopted there would be little trouble in regard to candle-power in the future.

MR. G. I. VINCENT (Des Moines): In the absence of any opportunity whatever either to examine the standard or to

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operate it I can only comment on it from the description in the text.

There is no question that if this apparatus remains accurate within reasonable limits that it will fill a long felt want. While it is quite true that tungsten lamps operated according to the directions for operating the standard will probably remain in constant condition for an indefinite period, I do not believe that this can be absolutely counted on. In other words, I believe that the electric standard should be standardized against a pentane lamp at reasonably frequent intervals.

The avoidance of all the manipulation required heretofore in using electric standards by the application of the wheatstone bridge is certainly very ingenious, and on the face of it is accurate.

The fact that the apparatus is portable is in my mind one of its chief advantages. Occasionally we have investigations made of street lighting with portable photometers, and the standards that have heretofore been used, as I understand, have not been very reliable. For permanent station work I do not see that this new standard has any great advantage over standards heretofore used. While it is true that the pentane lamp requires probably more skill to operate than the electric standard, it is possible in my mind to develop a secondary standard which is easier to operate than either one.

I have gotten over the difficulty in my own plant by constructing a holder with a capacity of about 170 cubic feet to supply the Edgerton standard which is used as the secondary standard on the photometer. The holder will supply the Edgerton for 6 days without refilling. It is located indoors so that its temperature never falls to a point as low as that to which the gas, which is used for filling the holder, has been subjected. In other words, the gas is always dry as far as hydrocarbon vapor is concerned and consequently there is no change of the hydrocarbon saturation in the holder.

To overcome any objection of the underwriters to having a holder of this type in-doors it is equipped with a safety de-

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vice without moving parts which automatically discharges its contents into the open air in event of a leak in the water tank or overfilling of the holder.

The slot in the Edgerton standard was enlarged to about double its normal size which gives it a value of about 12 candles. This moves the bar readings nearer to the center when measuring high candle-power gas and thus slightly increases their accuracy.

The Edgerton is tested against a Pentane lamp before filling and after filling the holder as this was found to be all that was necessary for continuous running. The maximum variation over a period of 6 days was 0.6 per cent. or from 11.77 candle-power when the holder was full to 11.70 candle-power when about empty. This is within the probable error of photometrical work.

This apparatus has now been in use for about 18 months, and has proven absolutely satisfactory. The operating cost including the standardizing against the pentane lamp every 6 days is not as much as that given for the electrical standard.

MR. E. C. JONES (San Francisco): The work of these gentlemen in evolving a standard is commendable. It is a deplorable fact that we have worked all these years in photometry without a dependable standard, and as the inventor of the Jones' gas photometer in 1879, when I put that little instrument into use, I think I may be absolved from commercialism when I say what I am going to say about photometry. Photometry as an exact science should be classed with the science of religion and politics. Many years ago I was in an Eastern gas works and there was an Irishman crossing the yard with his hands held apart and he said "Be gosh, Mr. Jones will you stand out of the way. I have a measurement between my hands." And all our measurements of light as we have taken them in the past remind me of the measurement between that Irishman's hands. By adding complications to our standard we do not eliminate the personal equation, and in consideration of photometry the personal equa-

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tion, the eye, which is the final arbiter of the comparison between gas and the standard is fallible. No two eyes are alike, and I have never known 2 experts in photometry who could agree within several per cent. in reading on the bar from the same gas. I hope to live to see the day when photometry will only be used for the comparison of the intensity of lights, for the comparison or illumination of different burners, and not for deciding the quality of gas. As I consider it to-day, it may be heresy. I know my paper on unstable hydrocarbon in illuminating gas read in California was considered as heresy at the time. But the day is coming when heat units will be the only standard. Candle-power to-day is a nuisance to the gas man and the consumer, and the consumer will soon learn it.

In regard to the paper read by these two gentlemen, it occurred to me that the electric standard might be extremely useful and fairly accurate, and it suggests itself to me that the new tungsten lamps filled with dry nitrogen instead of a partial vacuum, might be used to advantage as they have a fair life of well sustained candle-power and the globes do not blacken. Any improvement in lamps no matter how slight will improve the standard.

MR. G. I. VINCENT (Des Moines, Iowa): I just want to say that I entirely agree with the remarks Mr. Jones has made about candle-power. I think he is absolutely right, but there are some of us who *have* to measure candle-power whether we want to or not, and it seems to me what we ought to do, as long as we have to do it, is to measure as accurately as we can. And in constructing that secondary standard I described, one thing we had in mind was that the color of the flame was identical with the test flame to be measured, and also the fact that we had a large standard flame which gave a trifle more accurate readings.

THE CHAIRMAN: Any further discussion on that paper, gentlemen?

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MR. WALTON FORSTALL: I have something sent to Mr. Ramsdell from Mr. Uhlig.

MR. E. C. UHLIG (Brooklyn, N. Y.): In testing gas I have found that the ordinary works observer can obtain very accurate readings, and, as the adjustments are simple and easily understood, the services of a highly trained expert are not required. Aside from this in my opinion a great advantage is that only one observer is needed during a test.

Another advantage is that the lamp is unaffected by draughts or vibrations and can be used for testing after 2 or 3 minutes burning, thus saving the time usually spent in preliminary adjustments as in the case of pentane and candles. Also it frequently happens that when candles are used many tests must be discarded owing to the behavior of the candles, entailing loss of time in repeating the test.

Aside from using this standard for testing gas I have found it very useful in verifying the value of pentane lamps. It has happened that the steatite burner of a pentane lamp became cracked after long use. When a new burner has been placed in the lamp, the lamp is standardized and put into use, thus saving the time which would be lost were the lamp sent to the National Bureau of Standards.

This electric standard costs about $140 and will pay for itself in about 10 months when compared with candles, on the basis of 24 tests per day, assuming that 50 cents worth of candles are used daily. With the pentane lamp, which costs about $80 and ordinarily consumes a minimum of $45 worth of pentane monthly, the electric standard should pay for itself in about 2 months.

MR. C. O. BOND: Through coming late I have missed the preceding discussion, and I don't know whether any remarks I would have to make would be repetition or not; but we ought to welcome anything that will make more accurate our photometry. If those who feel that this device should be accepted with caution would run parallel tests, correcting for atmospheric conditions and using their pentane lamp as a check, and

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this method should prove out to their satisfaction, why then it should be accepted for use, and certainly so if it runs as cheaply as stated.

As has been stated, we are looking forward to calorific standards rather than photometric standards and I have believed for some time that our future photometry lies rather in the utilization than the testing of our manufactured product.

THE CHAIRMAN: If there is nothing further we will ask Mr. Millar to close the discussion on the paper.

MR. P. S. MILLAR (New York): It has been suggested that when employing the electric standard it will be advisable to check it occasionally against a pentane lamp. An interesting comment on this point is found in the statement of Mr. Uhlig who states that in the use of the lamp by the Brooklyn Union Gas Company it has been found valuable in checking pentane lamps where the value of the electric standard has remained constant and for some reason the pentane lamps have varied.

As a matter of fact there remains no question as to the reliability of the electric standard. If there were any doubt on this score it would be recognized at the Bureau of Standards and at other laboratories where the electric standard has been in use for years. These electric lamps are very constant, and as used to-day provide a measure of reliability which is not equalled otherwise.

In regard to the desirability of the Edgerton standard on the ground that its candle-power is relatively high, it is obvious I think that electric standards of any desired size may be used. In the particular case presented for illustration a 2 candle-power unit has been employed simply with a view to having a small source involving a small storage battery. When desired, an electric standard of 10, 20 or 100 candle-power or higher may be used. Of course in the case of the larger lamp a larger storage battery is required.

Mr. Jones has expressed the hope that photometry will be-

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come less important in the future, since as time goes on there is less interest in the candle-power of gas. I would suggest, on the other hand, that photometry is becoming more and more important in the study of lamps and in the design of illumination. This new field for photometry is of an importance which is now generally recognized.

The new development in tungsten lamps which Mr. Jones referred to is hardly applicable at this time to an electric standard such as that under discussion. In fact there is no need to look further for added reliability. Here we have a lamp which will not vary appreciably within a period of say 500 to 1,000 hours burning, and which for a small sum can be replaced by one or more other lamps with which it is interchangeable, each affording a check on the reliability of the others.

In closing I should like to emphasize Mr. Bond's remark —here in the electric standard is a device which on reputable authority is said to be of considerable potential value in the gas industry. Now let us try it. If it is not of value, it may be cast aside, but if it is tried thoroughly, I feel that you will find in it a very useful device.

MR. G. I. VINCENT (Des Moines, Iowa): I want to say here that I think Mr. Millar completely misunderstood my statement about street lighting. The story I have been told is that tests on street lighting that were inaccurate were not made with this apparatus and my idea is that this apparatus would undoubtedly have made those particular tests correctly.

THE CHAIRMAN: The next paper, gentlemen, will be "Automatic and Distance Ignition of Gas" by F. H. Gilpin, Philadelphia.

(Mr. Gilpin then read his abstract on the above subject.)

AUTOMATIC AND DISTANCE LIGHTERS.

Abstract.—PART I—INDOOR LIGHTING.—*Pyrophoric Lighters.*—These depend for their action upon sparks obtained from friction between a pyrophoric alloy and an abrading surface.

Catalytic.—These devices depend for the ignition of the gas upon

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the heating by the catalytic action of the gas of a fine wire of platinum or similar metal after the temperature has been raised by platinum black or electric current to a point high enough to start the action. In the D'Arsi auto-flame igniter the gas from a pilot flame is ignited by a platinum-black pellet in connection with small platinum wires. When the main burner lights, a thermostatic valve closes off the pilot flame. In the Lyons lighter a small spiral of platinum is heated by a small dry cell to 500° F. The filament is protected from direct impingement of the gas, but enough gas diluted with air reaches it to raise its temperature by catalysis to that of the igniting point of the gas. The Telephos lighter is similar in principle to the Lyons, but contains an electric cock operated by the ignition current.

Cocks for automatic lighting are operated by electricity through electro-magnets, compressed air by pneumatic push-buttons, and by an increase or reduction in gas pressure by means of a by-pass.

PART II—OUTDOOR LIGHTING.—Street lighting by hand is not satisfactory on account of cost of labor and waste of gas. An automatic distance lighter should be proof against unintentional derangement; all parts should be easily replaceable; it should not require attention of skilled labor; it should be capable of being installed by a fitter not especially trained for the purpose; it should be readily adjustable for pressure and, when set, remain unaffected by outside influence; in case of failure of operation it must be readily lighted by hand; it should be small in size; it must not be obstructed by naphthalene, but, if obstructed, should be easily cleaned; and, finally, it should quickly repay the cost of installation.

In the present state of the art, those appliances that operate on clockwork or pressure systems or a combination of the two are most readily adaptable for use, inasmuch as systems operated electrically or pneumatically are exceedingly costly in their initial installation.

The Horstmann, Shaw or "Automatic" and the "Rapid" are described as among those operating by means of clockwork, and the Bamag, Tourtel-Mealing, Broadberry, Gafeg, Lux, Kilchman and Gaulis, and Robson Automaton among the pressure wave systems.

Pyrophoric igniters are subject to atmospheric influences, and when wet or cold, their operation is slow and sometimes impossible. One of their chief disadvantages is that the active material wears out and must be replaced.

Platinum or palladium black lighters give the same troubles as the pyrophoric alloy and have the additional drawbacks of fusion and evaporation. The active life of the material is not long, and from 6 to 15 seconds elapse between gas admission and ignition. With the electrocatalytic platinum wire type, the deterioration occurs in the electric battery. Cells can now be obtained, however, that have a life

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of over a year, while the igniters will stand over 60,000 ignitions. Corrosion of contacts is a great source of trouble and these should be located where they can be easily cleaned.

Pilot troubles can be charged against a lighter only when the cock governs the action of the pilot. Extinction of the pilot upon lighting is often because the action of the valve is so quick that the pilot is put out before the main burner is lighted. Pilots inside the mantles give greater satisfaction than where outside, though this type must be non-luminous or mantles will carbonize. Where the pilot has a plug cock adjustment, condensation is apt to collect and obstruct the passage.

Every form of cock will eventually give trouble through leaking or sticking. Cone, plug and ball valves are liable to become corroded or foreign particles prevent their seating properly. Flap valves, if well made, act well, especially if the valve face is vertical, but rotary disk valves are probably the best type to use as the wearing surface is constantly self-cleaning and requires little or no lubrication.

In pressure lighters the tendency of the diaphragm to harden is remarkable. If the material be of poor grade, diaphragms are liable to almost total disintegration before serious trouble is noticed, while a superior grade may be lubricated with a neutral oil. Small diaphragms seem more subject to difficulties than large ones, particularly if in continuous contact with live gas.

Clockwork should be as simple as possible and separate means should be provided for driving the timing and operating trains. An important feature should be a definite relation between the tripping mechanism and the clock face to facilitate adjustment in use. All parts that are liable to screw up and bind should be guarded against.

General Summary and Conclusions.—The choice of the type of distance lighter depends almost entirely upon local conditions, the clock system probably being most satisfactory for scattered districts and the pressure wave system for congested localities. The combination of the two systems in one apparatus merely introduces the complications inherent in each.

Clock lighters are more subject to weather conditions than the pressure wave type, and more difficult to repair. They are independent of pressure, but cannot be controlled from a distance in case of emergency.

In transmission of wave pressures it has been found that a 0.4-inch wave will travel about 400 feet per second in a 30-inch main and 350 feet in a 4-inch pipe. In using this system it is necessary to have complete pressure control from one point, as wave from other sources, as outlying holder stations, could easily follow each other at such intervals as to annul the effects of the previous wave. Pressure wave lighters should be small, self-contained and selective in their action.

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Considering the small available motive force, a cock should be employed in which friction is almost negligible, or else higher pressures may be used. Mercury and seals of evaporative material should be avoided, and operative parts removed as far as possible from contact with the gas.

In spite of all handicaps inherent in the problem of automatic and distance ignition, much success has been obtained in England and Germany with both clock and pressure systems in addition to the saving effected in gas and labor charges.

INTRODUCTION.

The problem of a suitable means for ignition of a gas lamp, either of the open flame or incandescent mantle type, has long been in evidence. With the advent of electricity and its chief feature of convenience—its ability to be controlled from any location by a simple snap or knife switch—the need for a distance and automatic control of ignition for gas has become almost a necessity. The earliest attempts to obtain auto-ignition naturally inclined towards some scheme where a substance would of its own properties cause ignition of the flame, such as platinum black. Owing to the deterioration of such substances of this type as are now available, either from evaporation, fusion due to heat, or moisture absorption, the results obtained have not been entirely satisfactory. The introduction of the incandescent mantle burner and the by-pass cock and pilot gave the first directional impulse toward a satisfactory solution of the problem. The entire field of distance or automatic ignition is principally divided into two great classes—indoor and outdoor or street lighting. In the first class the situation is controlled by the consumer and restricted to single units or small groups of lamps at a relatively short distance, while in the latter the conditions are more readily controlled over a wide area through the distribution system of the manufacturer.

The first attempt at outdoor distance lighting was made in 1850 by Prof. Klinkelfuss, at Göttingen, but does not appear to have been successful. Since 1878 the solution of the prob-

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lem has been more generally attempted and in some cases very satisfactory results have been obtained. Several systems and means have been adopted to reach the desired end. These may be classified as follows:

(1) Pyrophoric.
(2) Catalytic.
(3) Electric.
(4) Pneumatic.
(5) Pressure-wave.
(6) Pressure-wave and clockwork.
(7) Clockwork.

In this connection might be mentioned the jump spark system of ignition, where the lamp igniters are a number of electric spark gaps in series with a high potential coil.

PART I.

Indoor Lighting.

By indoor lighting is meant that class of lighting where the time for ignition and extinguishing is controlled entirely by the consumer. For this type of service the pneumatic, catalytic, electric, pyrophoric and modified forms of pressure apparatus are most satisfactory. Many patents and schemes have been devised, but most of them have proven impractical in service. Below are given the description of a few of the systems that have been tested at the Photometrical Laboratory in the past three years. Most of the appliances were placed in regular service and not operated under what are usually termed laboratory conditions and, from the troubles experienced, the good and bad features that may be employed in designing a lighter are summarized.

Pyrophoric Lighters.—These lighters depend for their action on the ignition of the gas by sparks obtained from the friction between a pyrophoric alloy and an abrading surface, such as a small file. One of these is shown as attached on an inverted lamp in Fig. 1. A circular file is turned across a

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pellet of cerium-iron alloy, creating a shower of sparks which fall into the crown vents of the burner and ignite the issuing gas. A suitable attachment permits the device, when not in use, to rest out of the direct path of the heated products. In

PYROPHORIC LIGHTER

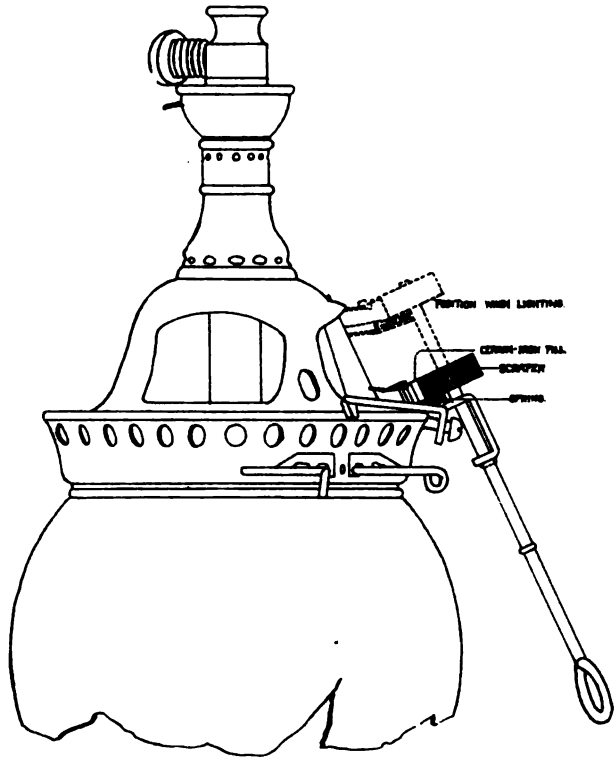

Fig. 1.

a variation of this apparatus the upward motion of the arm carrying the abrading surface also opens the burner cock. It has been claimed abroad that 4.6 grains of a similar alloy will produce 8,000 sparks.

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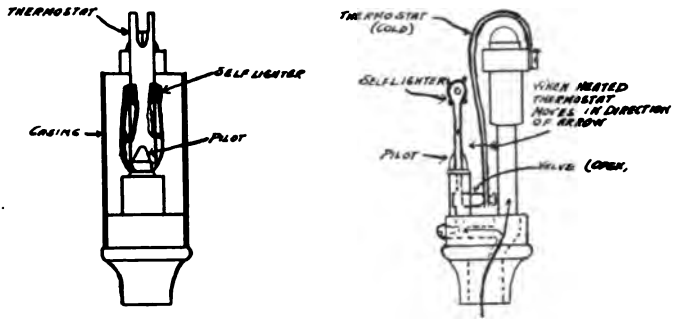
Catalytic.—These devices depend for the ignition of the gas on the heating of a fine platinum (or similar metal) wire by the gas itself to the kindling point after the temperature has been sufficiently raised by platinum black or an electric current to start the catalytic action by the gas.

D'Arsi Auto-Flame Gas Lighter.

In this apparatus, which is somewhat similar to the ordinary open-flame by-pass burner with small pilot flame, the pilot way is open when the burner is cold. On opening the gas cock the gas from the pilot is ignited by the platinum black



D'ARSI AUTO FLAME GAS LIGHTER

Fig. 2.

pellets in connection with small platinum wires. The main burner, when ignited from the pilot flame, heats a thermostat which, in expanding, pushes a small piston valve horizontally into the pilot gas way, closing it. (See Fig. 2.)

Lyon's Hot-Wire Igniter.

This device is shown in Fig. 3. It consists mainly of a small spiral of platinum, or similar, wire 0.002 inch in diameter, placed in a special attachment to the burner and is heated electrically to 500° F. The filament is protected from direct impingement of the gas by its location in a trough, but sufficient gas diluted with air strikes it to raise its temperature by catalytic action of the constituents, especially methane and

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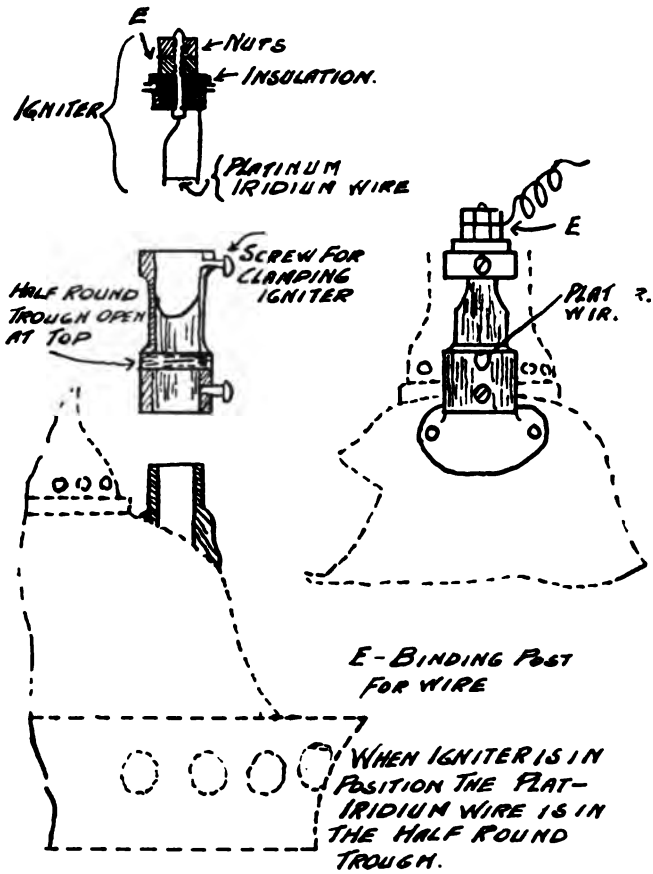
hydrogen, to the kindling point (1,500° F.), at which point the gas ignites. This apparatus is used in connection with a



LYON HOT WIRE IGNITER.

Fig. 3.

self contained fixture, having a 1.5 volt dry cell in the casing at the base of the drop.

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Telephos Igniter.

This igniter is shown in Figs. 4 and 5. It can be used either for upright or inverted lights. The lighting device is similar to the Lyon, in that a fine wire is heated by an electric current to ignite the gas by further catalytic action. In series

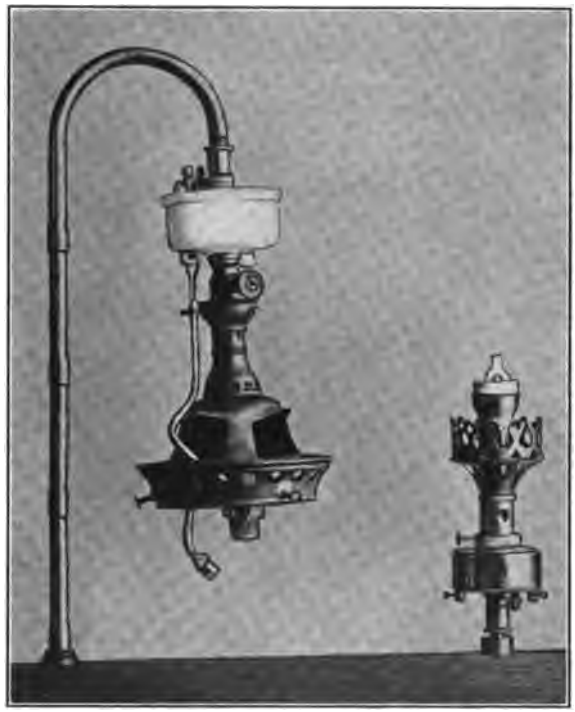

Fig. 4.

with the igniter the current actuates an electro-magnet that turns a flat ratchet disc valve, alternately opening and closing the gas passage. In the upright type the igniter is placed directly in the top of the burner cap inside the mantle, while in the inverted type the igniter is attached to a pilot jet. A small conical valve is raised, opening the pilot tube, by an inclined wire, which is pushed through an eyelet in the top of

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the valve when the armature is drawn towards the magnet by the passage of current.

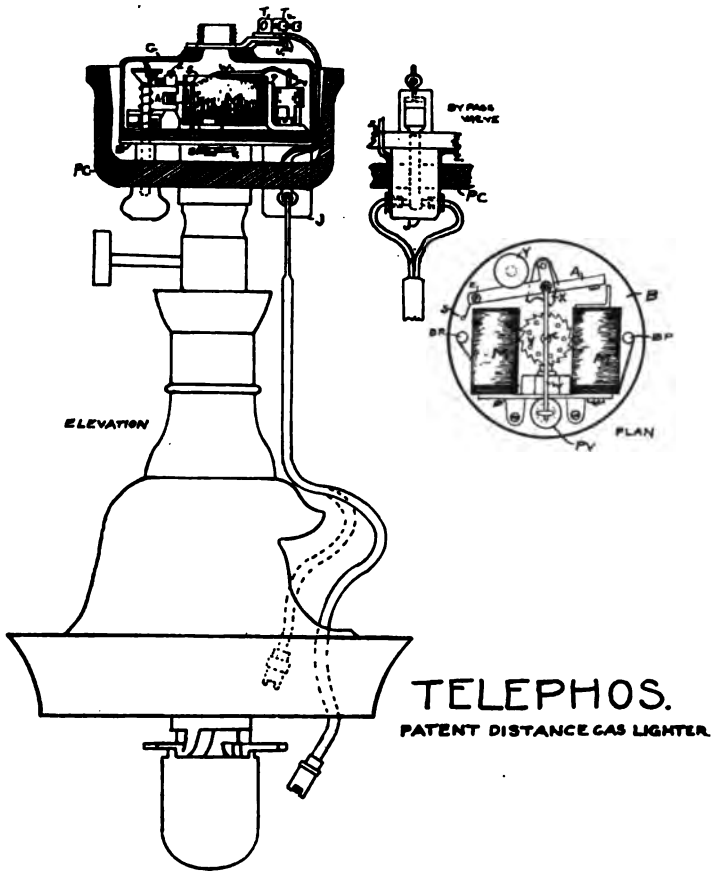

Fig. 5.

The inverted type is protected from the direct impingement of the exhaust products by a porcelain enclosing cup. The apparatus is operated by means of an externally located 6 volt special type cell and single push button.

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ELECTRIC.

Magnetic Cock.

The magnetic cock is operated with a by-pass integral with it. Two electro-magnets are connected in parallel, using the gas pipe for a return, and are operated by separate push

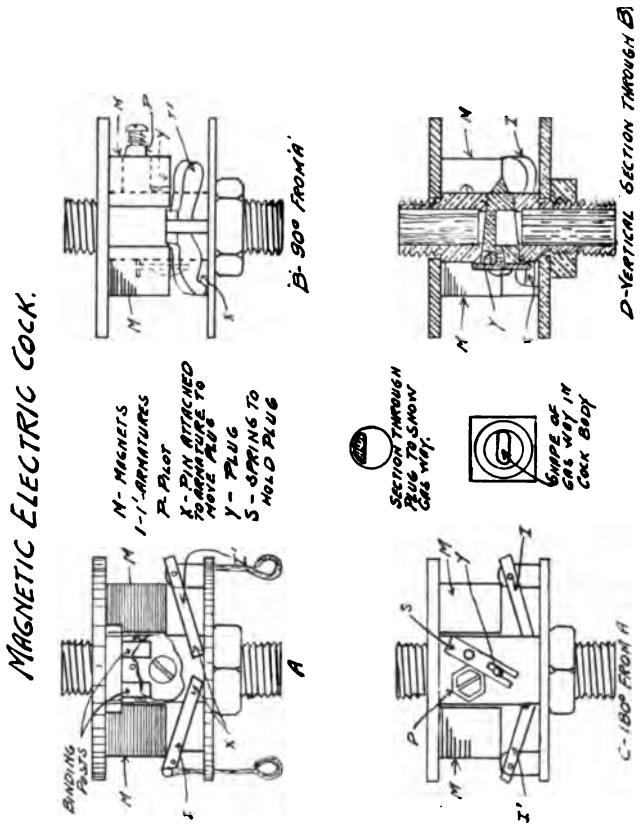

Fig. 6.

buttons. The cock barrel is rocked back and forth through 90° by the alternate strokes of the armatures of the two electro-magnets on a cam attached to the barrel. (See Fig. 6.) It is operated by three No. 6 Columbia dry cells in series.

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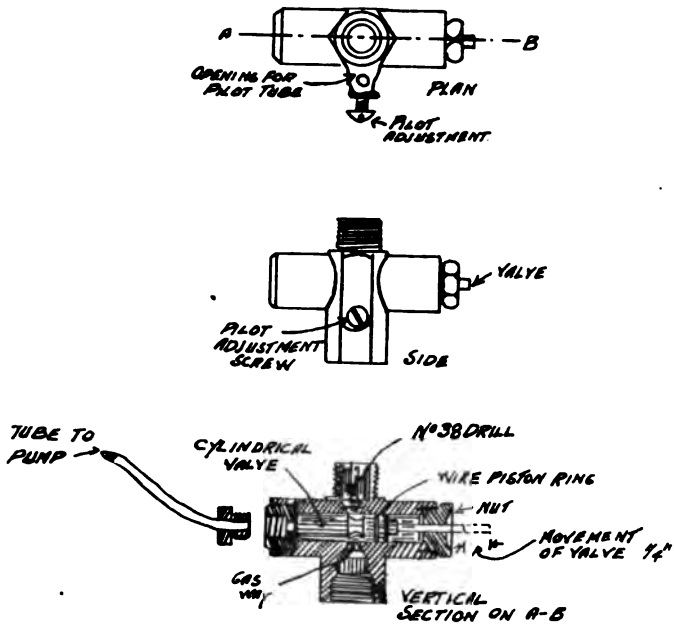
PNEUMATIC.

Positive Pneumatic Valve.

See Fig. 7. This appliance consists of a small horizontal piston valve across the gas way operated by the suction of a



POSITIVE PNEUMATIC VALVE

Fig. 7.

small plunger pump through a length of hollow brass tube about 0.08 inch outside diameter.

Luther Pneumatic Valve.

This device is shown in Fig. 8. The valve itself consists of two plungers connected axially by a rod and operated by vacuum or pressure. The rod carries a rack which turns a

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pinion on the valve stem. A helical slot in the pinion moving

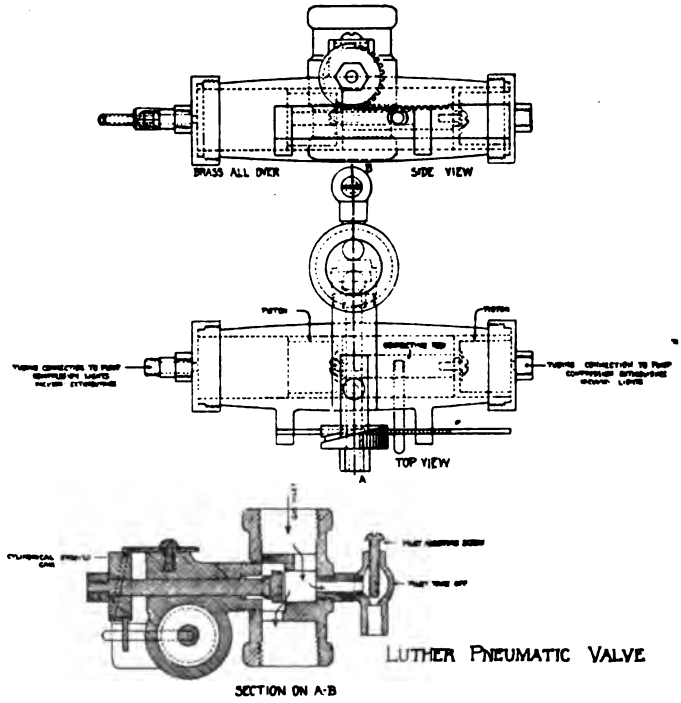

Fig. 8.

over a fixed pin gives it an axial motion that on alternate strokes unseats and seats the valve.

PRESSURE LIGHTERS.

The Askania.

This apparatus is shown in Fig. 9. It consists mainly of two parts—a regulator and an operator. The regulator may be placed anywhere in the gas supply line and has the appearance of an electric snap wall switch. By turning the switch to the left, full line pressure is admitted to the burner, while by turning it to the right a reduced pressure is maintained.

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This low pressure is regulated by a screw in a small gas passage. The operator is placed directly in the line over the lamp. When the by-pass in the regulator is open the small float and ball are in the lowest position, the ball closing the

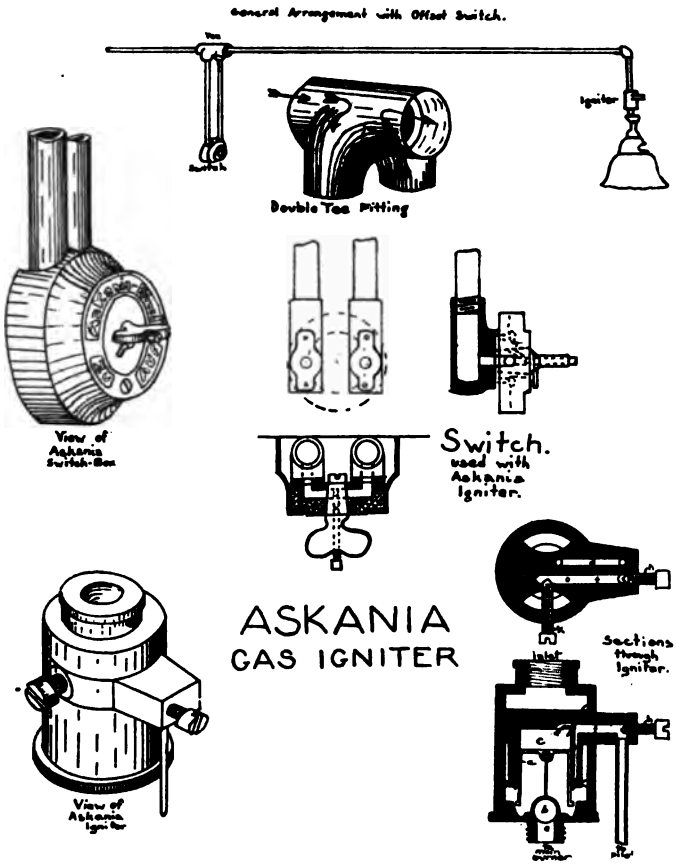

Fig. 9.

main gasway and the pilot being lighted. When the switch is turned "on" the increase of pressure causes the float to rise, opening the main gasway and shutting off the pilot. The float rises when the pressure exceeds $^{3}/_{5}$ inch water.

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PART II.

Outdoor Lighting.

As generally understood, outdoor lighting consists mainly of street and park lighting, all of which is under the direct supervision of the supplying company, especially as regards the time of the lighting and extinguishing of the lamps. Besides the general street lighting there are individual lamps or groups of lamps operated by the consumer for which the distance lighter can be used to advantage. For the last named purpose the magnetic cock, as described for indoor use, can be used, though the application is more limited.

Street Lighting.

The present system of lighting each lamp by hand can not be said to be entirely satisfactory. The large number of men necessary to cover a wide range increases labor cost while the necessity for beginning to light the lamps one hour before lighting time and the reverse at extinguishing time means waste of the gas needed to burn all the lamps the one hour extra. The average required lighted time of lamps is about 11½ hours. Taking 12½ hours as the average actual lighted time the saving due to lighting and extinguishing lamps simultaneously at the proper hour would be $1 \div 12.5 \times 100$, or 8 per cent., in gas consumption. For a 5 ft. burner this would amount to 1,825 cubic feet of gas per year per burner.

An automatic distance lighter should have the following essential characteristics: It should be proof against any unintentional derangement; all parts should be easily replaceable; its construction and manipulation should be so simple as not to require the attention of skilled labor; it should be able to be installed by a fitter not specially trained for the purpose; it should be readily adjusted to operate at any desired pressure, and, when set, must remain unaffected by outside influence; in case of failure of operation it must be readily lighted by hand; its size should be small, both for artistic and light economy reasons; it must not be readily obstructed by naphthalene

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and, if obstructed, should be easily cleaned and, finally, in a short time it should repay the total cost of installation by the saving effected in wages and gas consumption.

In the present state of the art those appliances that operate on the clockwork or pressure-wave systems, or combination of the two, are most readily adaptable for use, inasmuch as systems operated electrically or pneumatically are exceedingly

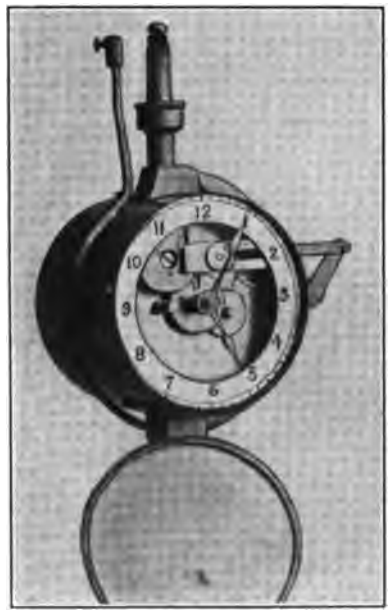

Fig. 10.

costly in their initial installation. Several of each type have been investigated in the last few years as below described.

The method of test is as follows:

When the lighter is received it is thoroughly examined and its method of operation determined by setting it up indoors in series with a governor for several days or a week. The system once determined, the apparatus is set in place on a lamp post, of which there are two sets of six on independent

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lines outside the laboratory. These lines are controlled by independently placed governors, though both may be operated in parallel on either governor.

CLOCKWORK SYSTEMS.

Horstmann.

This apparatus is shown in Fig. 10. The cock, which is of

Fig. 11.

the plug type, is placed outside the case containing the clockwork and is operated by a lever and connecting rod from a separate train of clockwork other than the timing works. Pins

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on the main clock dial release this secondary clockwork, which automatically shuts off when a disc carrying the operating pin has made one-half revolution. This pin creates a horizontal motion in the rod moving the clockwork lever one-quarter revolution.

Shaw (or Automatic) Lighter.

See Figs. 11, 12 and 13. The clockwork is of Seth Thomas make and is enclosed in a dust proof case. The valve proper

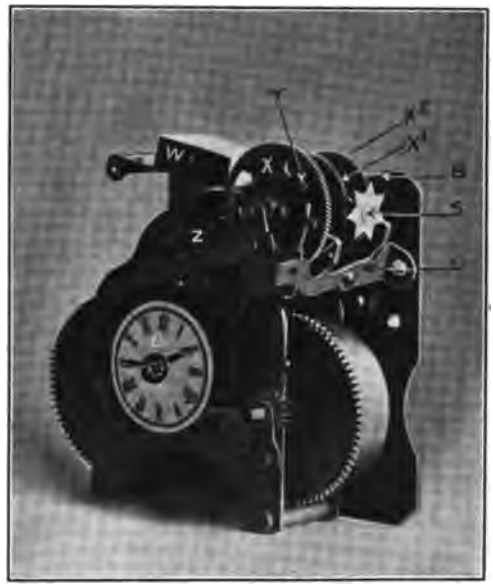

Fig. 12.

is at the upper end of an inverted "L"-shaped extension on the back of the box. The valve is a leather faced wedge that rocks from side to side, alternately closing the gas passages to the pilot and burner. This valve is operated through a system of levers moving over a dead spring center, as shown in Fig. 13. The clockwork train drives three operating pin wheels on the same shaft, which rotates once in 24 hours, the pins on

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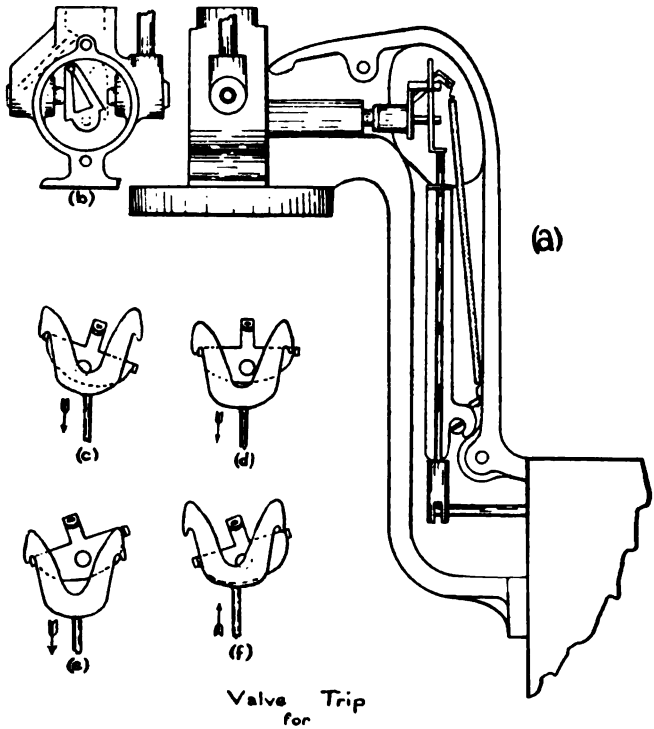
which can be set to raise the arms of the carriage bearing the weight at any desired time. The raising of the weight lifts a pin which in turn moves the rods to the valve. The front



Valve Trip for
1912 AUTOMATIC CLOCK LIGHTER.

Fig. 13.

wheel of the rear pair of operating pin wheels is a "lighting wheel" with fixed pin and the rear one is an "extinguishing" wheel similar to it. The relative times of lighting and extinguishing are automatically changed by means of a star wheel in connection with a double worm turning the operating wheels in opposite directions. The star wheel moves one notch back-

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ward every 24 hours, according to the location of the operating pin. The separate front wheel can be used for a fixed time of lighting by moving the front arm of the weight carriage to engage the pin. The operating limits are from light at 3.15 P. M. and out at 9.45 A. M., to light at 9.45 P. M. and out at 3.15 A. M. All parts of the apparatus are readily accessible for inspection and cleaning.

In the latest model of this apparatus only one pin wheel,

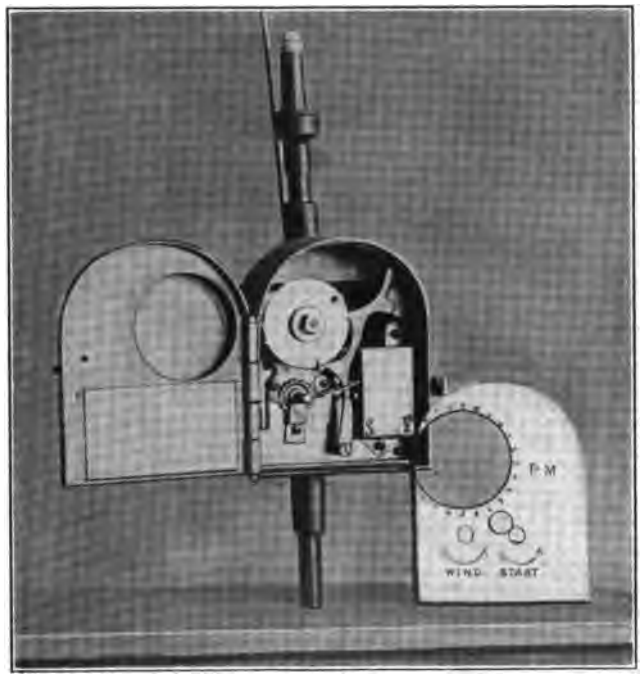

Fig. 14.

with two adjustable pins, is used to raise the weight arm that imparts motion to the lever system. The hours are marked on this wheel for convenience in setting. As the weight arm raises, the arm with the double hook at the top is raised to en-

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gage the lugs on the valve rocking stem, the operation of the valve taking place when the pin allows the weight to fall.

Rapid Clock Lighter.

This apparatus is shown in Fig. 14. The time dial carries two projecting pins that alternately move a lever to the right and left. Through a second lever a rocking semi-circular disc is turned to raise a cone valve off its seat in the main gas way.

Fig. 15.

The limits of setting are light 4-9 P. M. and out 11 P. M. to 7 A. M. It is enclosed in a reasonably dust-proof box 3½ x 4 x 2 inches, placed directly on the riser in the lantern head. In case of trouble with the valve, it would be rather difficult to get at to repair, as it is fastened on from the inside of the back of the case by screws.

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PRESSURE WAVE LIGHTERS.

Bamag.

See Fig. 15. A cast iron case is divided into two chambers by a diaphragm of fine, firm and uniform closely woven material impregnated with varnish. The gas pressure acts on one side of the membrane against a spiral spring on the other side, of which the tension can be readily altered by setting an adjusting pointer on the dial of the outside casing. The horizontal movement of the diaphragm is communicated by a system of levers to a ratchet and cam. This cam imparts to a rocking lever the motion that raises the cone valve off its seat. The operation of the apparatus takes three cycles, so that by using two styles of cam, half night and all night lamps may be operated on the same line. All the adjustments are on the exterior and easily made after the device has been placed on the post, irrespective of the differences in pressure in the various parts of the distribution system. By suitable levers the apparatus can be operated by hand in case of failure.

Tourtel-Mealing.

See Fig. 16. This apparatus consists of a double chamber regulator and a double diaphragm operator. On increase of pressure the seal in the regulator is broken and the gas pressure admitted to the two diaphragm chambers of the operator. By suitable arrangements of leak holes and springs the main diaphragm is pushed to the right, operating the ratchet valve. On the beginning of the pressure increase at the operator the secondary diaphragm operating against a spring closes the escape outlet of the main diaphragm. On release of pressure the opposite effect occurs and the main diaphragm is forced back by a counter balance to prepare for another operation. The valve is a rotating flat disc moving ⅛ turn at each operation of the diaphragm and having four ports for gas passage. All parts are readily accessible for cleaning and hand operation is simple.

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Broadberry.

See Figs. 17 and 18. The Broadberry is more or less a development of the Tourtel-Mealing type of apparatus, having

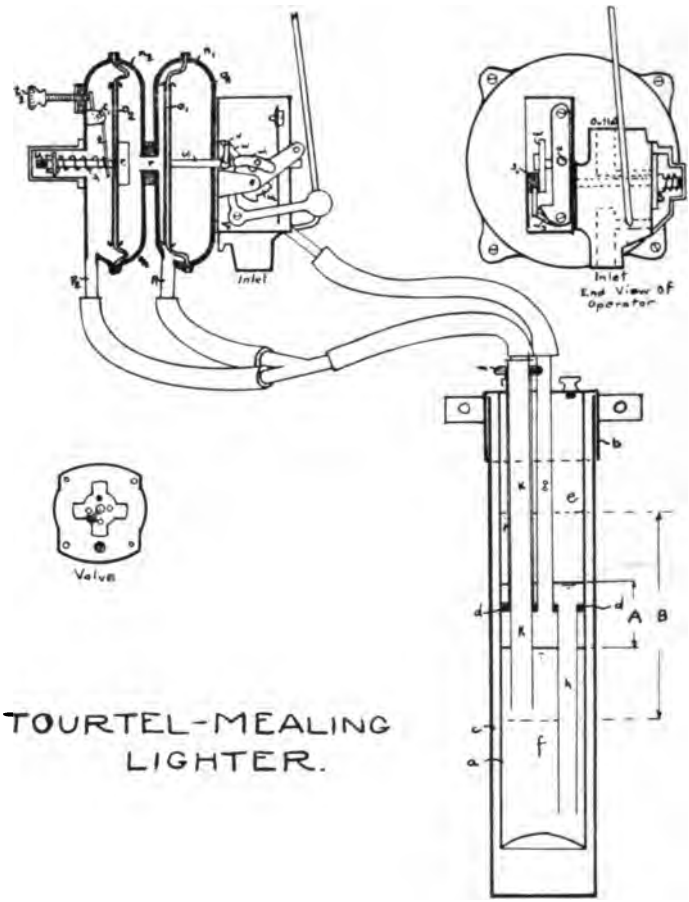

Fig. 16.

a controller and an operator. The controller is a cast iron case divided horizontally into two chambers. The lower chamber is open at the top to gas pressure and partially filled

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with a mixture of water and glycerine. When the gas pressure is raised some of the liquid is forced from the bottom of the lower chamber into the bottom of the upper

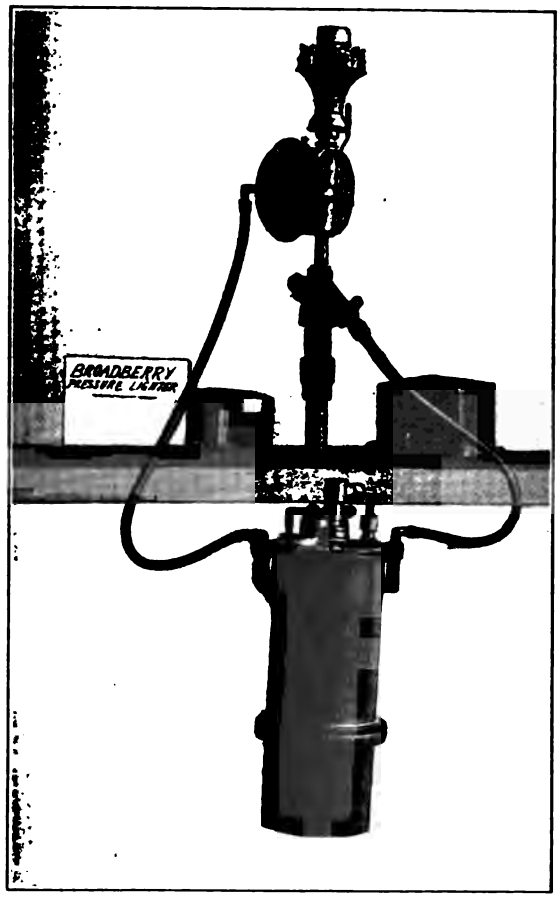

Fig. 17.

chamber which contains a float that rises and falls on quick impulses only from the liquid, a small pinhole in the bottom of the float allowing the balance to be maintained on

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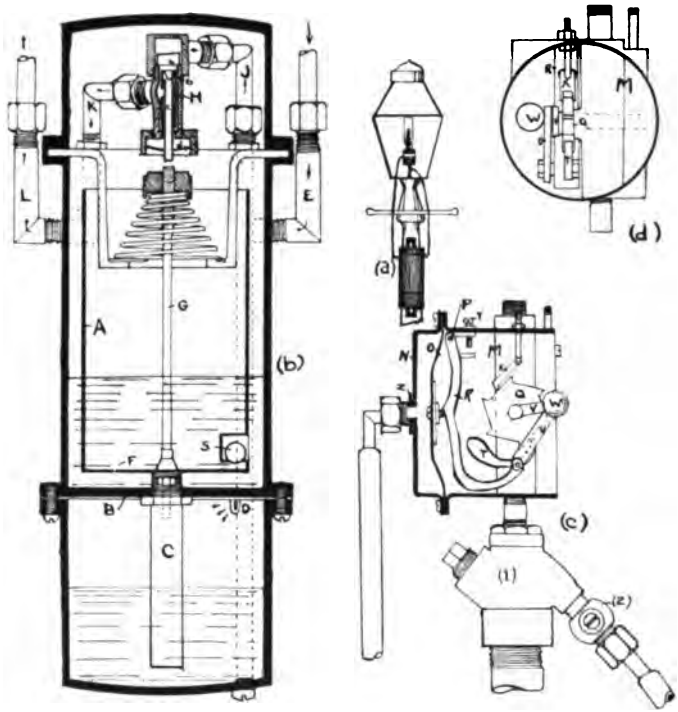
slow increases. On raising this float it strikes against a hollow valve stem extending down from a peculiar type of combination cone and clack valve, the flap raising the inlet to the diaphragm from the gas line and the cone regulating the out-



A.E. BROADBERRY APPARATUS
FOR
LIGHTING AND EXTINGUISHING
STREET LAMPS.

Fig. 18.

let through the hollow stem from the diaphragm to the air, raising it and admitting full gas pressure behind the diaphragm of the operator, which, through a system of ratchet levers

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moves the cock continually in one direction. When the float falls the valve stem falls and opens the back of the diaphragm to the atmosphere, allowing the ratchet levers to fall back.

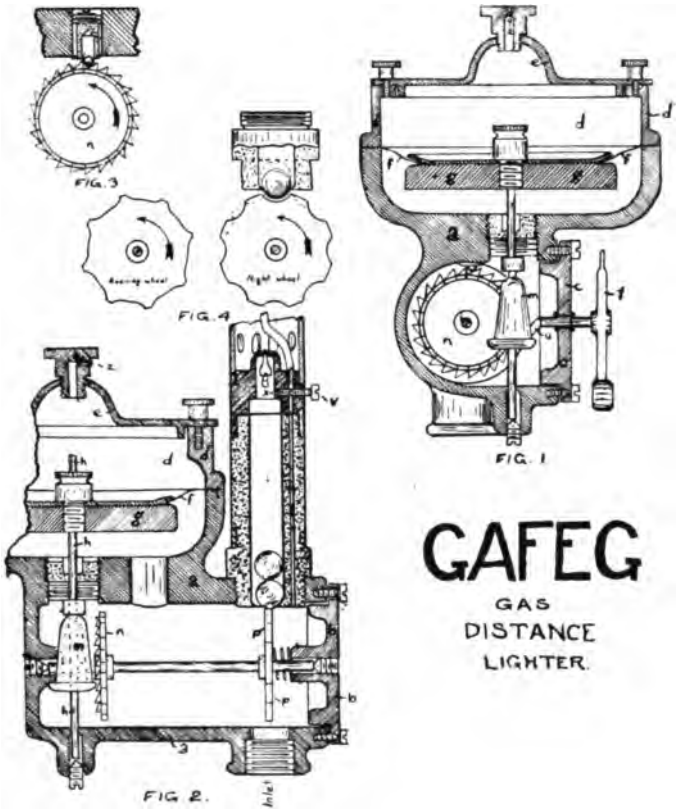

Fig. 19.

The only parts of the mechanism exposed to the gas are the diaphragm and the small valve operated by the float.

Gafeg.

See Fig. 19. A weighted diaphragm, on increase of pressure, rises, lifting a stem carrying a loose thimble-shaped pawl.

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The pawl engages in the crown teeth of a ratchet wheel which turns on the same axis as the lighting cam wheel. The cam wheel raises a ball valve to allow passage of gas. To prevent

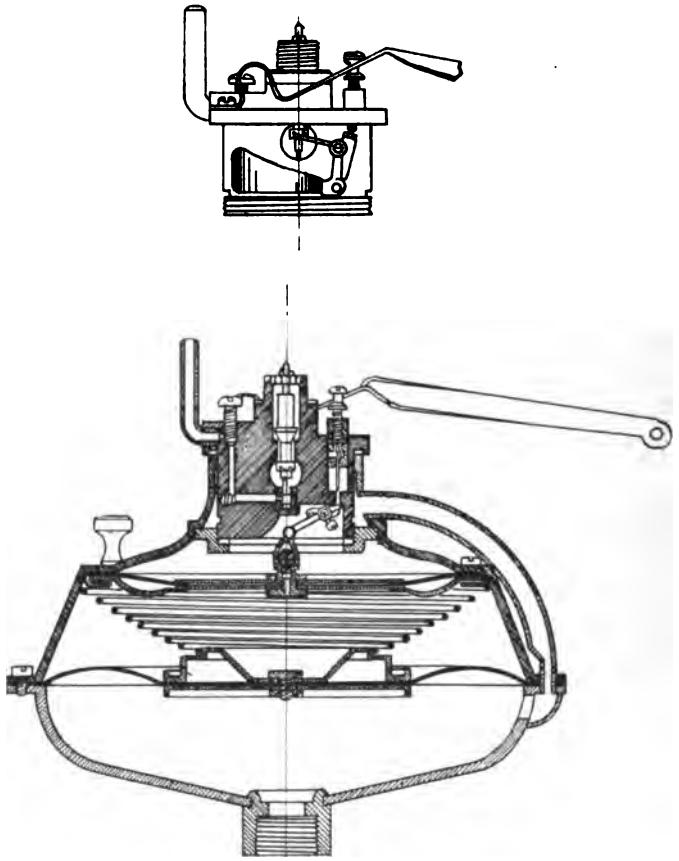

Fig. 20.

the ratchet returning a small ball rising and falling in a short tube, drops between the rim teeth of the ratchet and acts as a stop. The complete operation of this device requires three

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pulsations, and by changing the lighting cam all-night and midnight lamps may be operated on the same system.

Lux Lighter.

See Fig. 20. This type of lighter operates on the release of an increase of pressure of a definite amount for a definite time. The apparatus contains two diaphragms with a helical spring between. On small increase of pressure both diaphragms rise, lifting a series of levers to the "set" position. A small orifice in the center of the upper diaphragm permits the pressure between the diaphragms to fall so that the upper diaphragm recedes (the lever is held down by the helical spring). As the upper diaphragm recedes the lever system falls and the actuating arm turns the valve 1-6 of a turn. This valve is a combination vertical spindle cone and piston valve. As the cone closes the main gas supply the piston opens the pilot line. The casing is stamped iron and the entire device is extremely light.

PRESSURE WAVE AND CLOCK.

Kilchmann & Gaulis Lighter.

See Fig. 21. This apparatus is a combination of a simple pressure lighter and clock. On the increase of pressure beyond a certain maximum to which the diaphragm is weighted, the diaphragm rises, raising a trip allowing the clockwork to move. A cam in the clockwork raises a pin, which in turn raises a lever. This lever pushes up the valve rod. The valve consists of two copper balls with a spacer between, which are alternately seated, closing main or pilot way separately. A spring above the upper ball keeps the main gas way closed until the valve rod, acting through a diaphragm, raises them. The pilot light is an interior blue flame pilot.

Robson Automaton Lighter.

See Fig. 22. This apparatus is a combination pressure-wave and clock lighter, which may, by changing a cam wheel on the driving shaft be set to operate under a dozen different conditions. The clockwork drives a cam, which turns the cock of the ordinary tapered plug type. The release of the clock-

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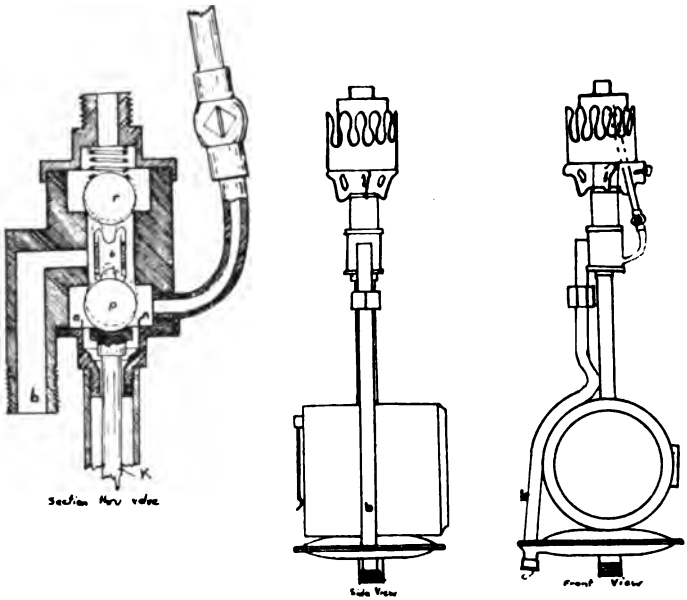

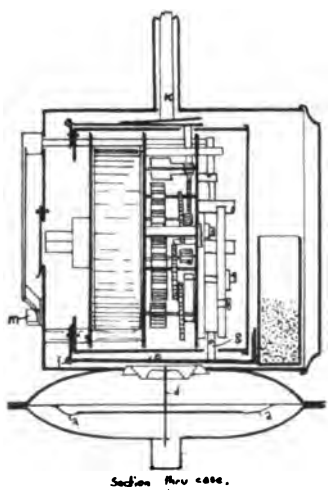

KILCHMANN
&
GAULIS
PRESSURE WAVE
LIGHTER.

Fig. 21.

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work is regulated by the motion of a varnished silk diaphragm (a) which moves the lower end of the lever (b). By a proper combination of the weights on levers (b) (b^1) and form of cam (d), the clockwork may be made to operate on either rise or fall of pressure. The height of the pressure wave may be different for lighting and extinguishing or the apparatus may engage just before the next operation or immediately after the previous operation, whether on rise or fall of pressure. As the clockwork will run for four weeks before

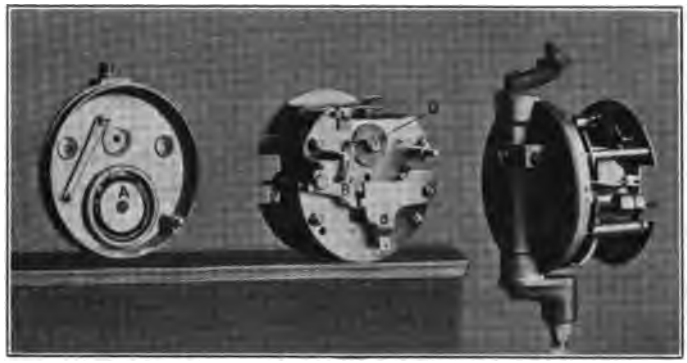

Fig. 22.

rewinding, very little attention should be required. The power required from the gas pressure need be sufficient only to trip the locking levers. By removing two nuts the entire clockwork may be detached from the riser for examination.

Criticisms on the Construction and Operation of Lighters.

As to the vital and weak points of lighters, let it be first said that all the ills to which any piece of machinery or apparatus in contact with gas is heir, seem to be intensified in the automatic lighter. Troubles that seem minor elsewhere appear glaring defects in an ignition device or an automatic controller. The points which should be considered in a criticism are, the ignition device, the cock or valve, the source of power and the operating mechanism.

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The ignition device may, or may not, be a vital feature of the apparatus. In pyrophoric or catalytic lighters it is the main feature. For the remaining types, it is not, as a rule, a prominent feature, especially where pilots are used.

Pyrophoric igniters are subject to heat, cold and moisture. When wet or cold their operation is slow and imperfect and in some cases operation is impossible. Heat increases their activity. One of the chief disadvantages of their use is that the active material wears out and must be replaced, the amount of use governing the length of time of service.

Catalytic lighters have many virtues and, *vice versa*, many faults. When platinum, or palladium black, is used, the same troubles are encountered as with the pyrophoric alloy, with the additional ones of fusion and evaporation. The active life of this material is apparently not long and its action not instantaneous, as from 6 to 15 seconds are required on an average from the first gas admission to ignition. With the electro-catalytic platinum wire type the situation is different. The deterioration disadvantage is shifted from the ignition device to the source of power—the electric battery. As, in order to avoid burning out the fine wire, the electrical balance is very carefully established, the life of the battery determines the continuous operation of the apparatus. Cells can now be obtained that show a life of over a year, while the igniters proper will stand over 60,000 ignitions. Corrosion of contacts is a great source of trouble and all such points should be located where they can be easily cleaned.

Pilot troubles cannot be charged directly against a lighter, unless the cock or valve used governs the action of the pilot. In the case of the feature where the pilot is extinguished on ignition of the main burner, very often the action of the valve is so quick that the first is extinguished before the second is ignited. Pilots placed inside the mantle give greater satisfaction than outside pilots, though this type must be non-luminous or mantles will carbonize. Where the pilot has a plug cock adjustment instead of a needle, the tendency for drip to collect

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and, by freezing, stop the gas way in cold weather, is greatly increased.

Cylindrical plug cocks wear down, and as wear cannot be taken up, leaks will occur. In the tapered plug type where provision is made for automatically taking up the wear, the friction gradually increases and the torque necessary to operate is consequently increased. Lubrication of plug cocks, especially outdoors, is quite a problem. In cold weather the drip, even in the small quantities that form, will dissolve almost any lubricant used in about a month or six weeks, leaving the cocks dry and tight. Indoors this action requires five or six months to cause trouble. Piston valves require some type of packing and in two or three years will develop a permanent leak. Cone, plug and ball valves are liable to become corroded and coated so that they do not seat properly. If they seat from their weight alone, small foreign particles are liable to cause leakage by creating an eccentric action. Flap valves require greater care in workmanship to ensure tightness, but if well made their action is good, especially if the valve face is vertical. Rotary disc valves are probably the best type to use, as the wearing surface is constantly self-cleaning and requires little or no lubrication.

In pressure-wave lighters, the life of the diaphragm is of utmost importance. Their tendency to harden is remarkable. If the material be of poor grade, diaphragms are liable to almost totally disintegrate before any serious trouble is noted, while, where a superior grade of diaphragm material is used, suitable means can be provided for lubricating with a neutral oil. Small diaphragms seem more subject to difficulties than large ones, and especially so if in continuous contact with live gas pressure.

Clockwork should be as simple as possible, and separate means should be provided for driving the timing and operating trains. A very important feature should be a definite relation between the tripping mechanism and the clock face to facilitate adjustment in use. All parts that are liable to screw up and bind

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should be guarded against. The operating mechanism should contain the minimum number of bearings possible and be positive in action.

General Summary and Conclusions.

The choice of the type of distance lighter depends almost entirely on local conditions. Where the system is greatly spread out and the location of lamps scattered, the use of clock lighters would probably be most satisfactory, while for more or less congested districts the pressure wave system is more in order. The combination of pressure wave and clock in one apparatus merely complicates the adjustment and the attention required of each type, though where the pressure of the gas is low it could be used to advantage on a pressure-wave system.

Clock lighters are more subject to weather conditions than the pressure-wave type and when out of order more difficult to adjust and repair. They are independent of pressure conditions, but also when once set to operate at a specified time cannot be controlled from a distance in case of emergency.

In the problem of the transmission of pressures to actuate pressure-wave distance lighters, it has been found that a 0.4 inch wave will travel about 400 feet per second in a 30 inch main and 350 feet per second in a 4 inch main. In all problems of this type it is necessary to have a complete pressure control of the entire district from one point. Waves emanating from sources, such as outlying or separate holder stations, could easily follow each other at such intervals as to annul the effects of the previous wave. Where the entire distribution system is fed from a number of scattered holders, it would be necessary to confine the range of each holder to an isolated district, if pressure-wave lighters were used.

Pressure-wave lighters to be satisfactory should be small, self contained and selective in their action. Barrel cocks, especially those of taper construction, are liable to stick and

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require considerably more force to turn than can be obtained from the action of a small diaphragm, or even by clockwork.

When one considers that from a 3 inch diaphragm with a 4 inch water pressure the total available force is only $9\pi \times .579 = 16.5$ oz. or about one pound acting on a very short leverage, it is readily seen how an only ordinarily tight plug cock would prevent proper operation. One solution of this lies in the use of one of the numerous types of cocks in which friction is more or less negligible. Another is the use of higher pressures in the distribution mains, under which conditions also the slight increase in pressure necessary to start operating mechanism would be a smaller percentage of the whole.

There are various types of cocks or valves available that are not only tight but afford little friction in their movement. Mercury seals should be avoided, owing to their corrosive action. All evaporative seals cause more or less trouble if not regularly inspected. All operative parts should, as far as possible, be removed from contact with the gas; as it generally causes corrosion. The action of the apparatus should be selective, should respond to only a certain type of impressed wave and should not be affected by gradual rise or fall in pressure, due to normal operating conditions. The ideal perfect lighter should have almost human intelligence and, like the Sun valve in use with acetylene lighting in the Lighthouse Service, turn itself on and off at a certain predetermined minimum intensity of illumination.

In spite of all the handicaps inherent to the problem of automatic and distance ignition, considerable success has been obtained in England and Germany with both clock and pressure wave systems in addition to the financial profit incident to their installation in saving of gas and labor charges.

THE CHAIRMAN: Gentlemen, we have just listened to another excellent paper and it is now open for discussion. Mr. Gould, we would enjoy very much having you open the discussion on this paper.

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MR. J. A. GOULD: I received a request to speak on this so late that I did not have all the data at hand, so I would rather not speak at all about it. I am not prepared.

THE CHAIRMAN: This is a paper, gentlemen, in which we are all greatly interested.

MR. E. C. JONES (San Francisco): My experience is not recent enough to be of any value. That is, it is 10 or 12 years ago, and the evolution and improvement in the art has been such that it would be too old fashioned.

MR. R. C. KELLOGG: I would like to ask Mr. Gilpin whether or not there have been any experiments conducted on automatic lighting, using that Swedish invention which is used in buoys and light houses and inaccessible places along the sea coast, where they have an automatic valve that opens at sunset and closes at sunrise, using acetylene gas.

MR. F. H. GILPIN: I have seen the valve and I understand it is not used on the buoys. They use the patent valve, but the sun valve is only used where the light is permanently fixed, not on the buoys.

MR. R. C. KELLOGG: So they can get at it?

MR. F. H. GILPIN: I do not know what the reason is.

MR. R. C. KELLOGG: I know they have them all over the Swedish coast.

MR. F. H. GILPIN: They are a beautiful piece of mechanism.

MR. E. C. JONES: One matter in my experiment in this form of light, several years ago, may be interesting, and that is I found in using platinum black for the mica that if the button of the platinum black was placed in the main burner often times it would fail to act, and the flame of the burner, and particularly the radiant heat of the flame, would reduce the activity of the substance. I found that by using a stopper bar through which a by-pass hole was built the button on the stop bar provided a small pipe well out of the way of the main burner, so when the stop cock opened the gas flows first through the by-pass pipe and the jet of gas impinged

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upon the button and ignites, and as the battery on the stop cock is open it is ready to ignite the main burner, and then by fully opening the stop cock the pilot is shut off. It was rather an ingenious device.

MR. F. H. GILPIN (Philadelphia): That is the same principle as the D'Arsi one. There is probably not much information from actual experience in this country, because automatic lighters are practically new. There are not enough of them in any one town for anyone to obtain information that would be of value to anybody else. Local conditions affect the results greatly.

THE CHAIRMAN: Are there any questions that you would like to ask Mr. Gilpin?

MR. JOS. P. KANE (Port Chester, N. Y.): I would like to ask what method of inspecting and replacing defective mantles is used where the system is in use.

MR. F. H. GILPIN: Which system in particular? The automatic lightings?

MR. JOS. P. KANE: The automatic lighting.

MR. F. H. GILPIN: The information at hand does not come from any large experience of individual experimenters. I presume the method would be the same as any other mantle street lighting system. Of course, you would have to clean the globes and replace broken chimneys and mantles, although it is claimed that the mantle breakage is much less. There is a great saving in mantle breakage, and you save 8¼ per cent. of the gas by instantaneous ignition.

MR. J. D. SHATTUCK (Chester, Pa.): I think adopting this system practically means sending one lamp-lighter over the entire district on a motor cycle to look out for defective mantles and lamps. We have been experimenting with 2 or 3 clocks for several years, and finally adopted one, equipping 27 lamps with these clocks. We expect to gradually extend their use, getting our experience as we go along. We do not seem able to find anyone who has used clocks long enough to give us any absolute guarantee of success.

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MR. WALTON FORSTALL: I would like to ask Mr. Gilpin whether as a result of the investigation he has made on these various forms of automatic and distance lighters he would be willing to equip any large system of street lamps with any of the forms that he has investigated, without mentioning the names.

MR. F. H. GILPIN: I think it would be a safe proposition. Your local conditions will affect it, what your labor charges are, and what your lighting hours are.

MR. WALTON FORSTALL: Then as I understand it, it is purely a question of expense. There are on the market 1 or 2 systems of lighters. If it turns out you believe you will save money by any change you might make you can depend on these lighters to do the work they claim.

MR. F. H. GILPIN: There are several lighters on the market that will give less than 2, and probably not more than 1 per cent. failures. That has been found by actual test of installations of 500 or more abroad. Now, that was several years ago, and there have been many improvements since then.

MR. M. H. SPEAR (Flushing, N. Y.): I should like to ask if there is any city or large town that is fully equipped with these distance lighters?

MR. F. H. GILPIN: In America?

MR. M. H. SPEAR: Yes, in the United States.

MR. F. H. GILPIN: I don't know of any towns that have a very large number. I have seen them in quite a number of towns, and some of them have been put in quite recently. In the last 6 months I have noticed them in a great many places. I had not noticed them before. Abroad, in some German towns, they have pressure lighters, particularly on the Bamag system. That is not very satisfactory here. They are very well satisfied with them. They claim considerable saving per annum on the lamps. The types mentioned in those cities I have not seen mentioned here in American pub-

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lications. They seem to be exclusively of the British or German type, and they seem to remain there.

MR. FRANK F. TRIPP (Newton, Mass.): The city of Newton, Mass, is entirely equipped with those lamps. I think they have 1,042 in operation for the last 3 years, and so far they have been very successful.

MR. E. C. JONES: What is the type of lighting apparatus used?

MR. F. F. TRIPP: Clark, with the pilot light attached.

THE CHAIRMAN: What kind of gas have you: water or coal gas?

MR. F. F. TRIPP: Water gas, the same as in Boston.

MR. J. A. GOULD: It is a mixed gas.

MR. THEODORE BUNKER (Paterson, N. J.): I intended to speak, but the last speaker has entirely knocked the wind out of my sails by stating that he has an installation of 1,000 lights operating satisfactorily with a clock mechanism. I was going to tell of our experience in Paterson with an installation of 400 clocks, which proved unsatisfactory. They worked well during the summer months, but in the winter we had a great deal of trouble. The increment of saving is so small and the number of expert clockmakers required at night to keep the mechanism in order so great that we found we were losing money and removed the clocks.

MR. JONES: Out in California we have a rule that lanterns shall always be kept clean. That does not mean once a week or once a month. It means all the time. And out there we have what are erroneously called trade winds in the summer, and a good deal of dust is carried with these winds, and sometimes it is necessary to clean the globes every day, sometimes once a week, and sometimes twice a week, but I think with the automatic contrivance there ought to be an automatic lantern cleaning device, and an inspecting device to record the conditions of the mantles and the glassware.

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MR. C. O. BOND (Philadelphia): It might be interesting to Mr. Jones to say that the same complication is present on the electric light.

MR. E. C. JONES: I do not know anything about electric lighting.

THE CHAIRMAN: If there is nothing further we will ask Mr. Gilpin to close the discussion.

MR. F. H. GILPIN: I think I have answered most of the questions, but might say in closing that 90 per cent. of the troubles you find with automatic lighters is due to the cock; the cock will stick or get gummed up and will not operate, or something like that, but if the cock mechanism is all right, the lighter mechanism generally works all right.

THE CHAIRMAN: Mr. A. D. Whittaker is the author of the next paper and he finds it very difficult to be in two places at once. At the present time he is engaged in discussion in the meeting, Section A, so we are going to impose upon Mr. Forstall's good nature again and ask him if he will kindly present the abstract prepared by Mr. Whittaker.

(Mr. Forstall then presented abstract of Mr. Whittaker's paper on "Organization and Equipment For and the Method of Handling Street Leaks.")

MR. ALAN D. WHITTAKER (Atlanta, Ga.):

ORGANIZATION AND EQUIPMENT FOR AND THE METHOD OF HANDLING STREET LEAKS.

Abstract.—The methods employed in caring for street leaks in Boston, Chicago, New York, Philadelphia and St. Paul are given in detail. All of these cities are divided into districts with a shop in each district; in some cities a man is sent to the scene of the complaint, either to do what he can, and to telephone for assistance if necessary, or in other places to report to the office and if necessary obtain instructions. In New York, an emergency automobile with a full equipment of tools and men is rushed to the spot. As a rule no special crew is kept on duty, the location of all street gangs being kept on file at the office so that men may be collected as needed.

It does not appear to be the rule to keep emergency gangs on duty

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all night, as in all the towns mentioned except Boston the method is to notify the men at their homes when their services are required. In Philadelphia a regular detail of men is notified to remain at home all night to be ready in case of necessity.

The organization of the force, the duties of superintendents, foremen and others, methods of handling orders, etc., are described for each city in great detail.

The course of the mariner is beset with uncharted rocks, floating derelicts and icebergs; the railroad engineer faces possibilities of broken rails and open switches; the gas engineer must ever be alert against the dangers of leaking gas.

As the mariner must pay great heed to the wireless message that warns him of the icebergs, as the engineer must not close his eyes to the horizontal semaphore, so the gas engineer must regard the report of a leak as something that takes precedence over all other affairs. It is a bomb with a time fuse.

No matter how many false alarms come in each new leak reported must be regarded as the one that is going to devastate life and property.

Every one in the gas company's organization from janitor to president should know exactly what to do with a leak complaint should it come by chance to him.

It is through the public that we get reports of leaks. Fortunately the public is prone to report gas leaks. Of course, they overdo the matter, and a large bill is often the cause of an excited telephone message about a big leak. But it is well to accept lots of chaff with the wheat, for we should in no way discourage this tendency to report leaks, imaginary or real.

Careful questioning by the complaint clerk who receives the notice over a telephone can eliminate a good deal of uncertainty. However, it is not a time to take anything for granted, and someone from the gas company must get on the ground quickly with sufficient equipment to locate the leak and stop it or rob it of its danger to life or property.

How this is done is best described by the reports received from several of the larger cities. These reports are presented

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here in full and it is to the courtesy of the gentlemen who prepared these reports that the members of the Institute are enabled to have this important matter so brought before them.

Smaller cities cannot carry the organization described in these reports. However, it should be arranged in any size of town that someone in authority should be informed of a leak any time day or night.

If there is no night complaint man on duty all night, the telephone operator can receive such complaints. If there is no night telephone operator, arrangements can be made with the central telephone exchange to call up the superintendent or any employee designated. The police and fire department also make possible satisfactory arrangements for notifying the proper person.

Very fair emergency equipment can be kept even by very small plants, if the matter is given careful consideration.

How to get the men out and the tools to the job are details on which the superintendent can exercise his executive ability and get results with equipment that at first might seem hopeless.

Readiness to repair leaks, of course, must not take the place of the most careful construction work.

It is very proper to have men and equipment to handle leaks if they develop, but no leaks should ever occur from faulty work.

The leaks that we prepare for should be caused by forces beyond our control.

Organization and Equipment for and Methods of Handling Street Leaks.

By Boston Consolidated Gas Company.

Division of Territory.

The territory is divided into 6 distribution districts. These districts being practically identical with the districts supplied

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by the 6 independent distributing companies that were consolidated into the present company.

In each of these 6 territories a main, service and jobbing force is maintained which handle all complaints in their several districts.

Each local office has a telephone connection with the public exchange and a private line connected to switchboard in the main office at 24 West Street, where operators are on duty all the time.

Course of Leak Order.

When the report of leak is received by the telephone operator, she immediately plugs in the complaint telephone of the jobbing office and the details of the complaint are received by the clerk in that office. A leak ticket is made out, stamped with a time stamp, and is immediately given to a local jobber or is transmitted by private telephone to the proper suburban jobbing office.

A memorandum of the complaint is recorded in the leak record book, and if the complaint comes from an outside district, a copy of the leak ticket is sent to the office in that district.

The Jobber's Part.

A jobber starts for the location of the leak as soon as the complaint is received. If he finds it to be a street leak, he immediately telephones for the emergency gang of the main department who locate and stop the leak.

In the meantime the jobber ventilates the building where the complaint originated, inspects adjacent buildings, collects data for an accident report if there should be any complaint of sickness, and remains on the job till all danger is past.

If there is good evidence on the first complaint that the leak comes from the street, a gang from the main department may be sent immediately without waiting for the report of the jobber, but a jobber is sent in every case.

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Night Jobbers.

At the main office and one other district, jobbers are on the floor all night, while in four districts they are on the floor till 10 P. M. and sleep in the building after that hour, subject to call.

The men take their turns on night duty in rotation, serving one week every month in most cases.

A night watchman wakes the men when a complaint is received, except in one office where the men are roused by the telephone gong.

On Sundays and holidays the men also serve in rotation.

Street Emergency Men.

The organization of the emergency men of the street department in different districts varies according to local conditions.

In the city proper there are day emergency gangs of four men maintained at three different points and at least one night gang throughout the year, with a second night gang when conditions require it.

Night Emergency Men.

One night gang is on duty through the year to cover two adjacent districts which are semi-suburban, and men are always available during the day at the local headquarters of both districts.

In the three suburban districts no night emergency men are maintained during the summer, and not always during the winter, depending upon the character of the winter.

The night emergency work in these districts is well handled by calling men living close to the local offices, and there are always men available during the daytime. On holidays a gang is maintained at all the local headquarters, as otherwise it would be difficult to call in a gang if needed.

If one district where the tendency was for the men to move from the vicinity of the local office to secure cheaper rents, we have made it an inducement for a few men to remain and hold themselves in readiness for emergency calls by paying them $5.00 per month extra.

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Equipment.

Our equipment for handling leaks is less elaborate than in some companies. By working from 6 centers the transportation problem is greatly reduced.

We have not adopted automobiles for emergency work except in so far as the superintendents' machines are used, but still depend upon horses.

In the city proper, with emergency men at three points, they can reach the trouble quickly on foot, but the superintendent's touring car helps in a real emergency and in transferring men from one job to another.

At the station where one night gang looks after two districts, there is an emergency team always ready to transport the men.

At the three outside stations a horse must be harnessed by the watchman when the call is at a distance from the stable.

Both jobbers and street men are furnished electric flashlights.

From the above you will note that different districts require different organizations.

We look after 935 miles of mains but our troubles are mostly concentrated in certain congested districts.

The building of a double system of sewers and numerous subways is a great source of trouble in our mains, added to the fact that a large part of Old Boston is made land on a mud foundation.

J. A. GOULD,
Engineer of Distribution.

METHOD OF HANDLING STREET LEAKS IN CHICAGO.

Division of City.

The City of Chicago is divided into four divisions, conforming to natural geographical boundaries.

Supervision of Leak Work.

The supervision of leak work is conducted by the regular street department organization, the overhead organization

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being as follows: the general superintendent, the assistant general superintendent, and the superintendent of mains and services, with headquarters in the main office. Each division is under the direct supervision of a superintendent, and an assistant superintendent. The superintendent of pressures, with headquarters in the main office, is also in the street department organization with respect to the main system.

Main System.

The main system is divided into two parts, feeder lines and low pressure distribution mains, gas being transferred from the feeder lines to the distribution system through district governors.

Shop Records and Messenger Service.

Every opening in the street, whether made for the repairing of a main or not is reported on a regular main ticket which is filed away in the main office as a matter of record.

In each division shop there is originated a sheet showing the location of each gang, whether it be a main or service gang, and a copy sent to the main office. In the event of an emergency arising which requires the services of workmen, a gang in the vicinity of the trouble can be reached by motorcycle or by other means if they are known to be out of reach of a telephone, and sent to the scene.

Force of Men on Duty.

There are no special leak repair gangs on duty at any time, either day or night. The regular force of men is sufficient to take care of any emergency which may occur during the day. During the night, men who live in the vicinity of the break or leak can be either quickly notified by telephone, or picked up by the emergency truck. All of the men are subject to call any time during the day or night, Sunday and holidays not excepted.

Feeder Lines.

The feeder lines are regularly patrolled, every point being covered two or three times each week. By this means a close

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watch is maintained and in many cases trouble avoided by conditions being reported before they become serious. These men walk over the main, and raise manhole and catch basin covers, in order to detect any odor of gas in the immediate vicinity of these lines. They investigate any instances which might indicate a leak, and report the condition of the line to the superintendent of the division at the close of the day.

Handling Leaks.

If a leak is discovered during the daytime by the feeder line patrol, he immediately telephones to the division shop, giving all details. The shop notifies him of the location of the nearest gang, and either instructs him to go for the gang himself if it is in his immediate vicinity, or if it is too far away, instructs him to act as a watchman until other men get there. In the latter case, if the gang can be reached by telephone, this method is employed, or if no telephone communication be possible a man is sent on a motorcycle to notify them. It may be that neither of these methods are practicable, in which event, the emergency truck is sent to gather up a gang, and carry them to the location of the leak.

The superintendent of the division notifies the general superintendent and goes to the scene. The latter notifies the superintendent of mains and the superintendent of pressures, the former going to the location of the leak, the latter making all arrangements to shut down the line if this becomes necessary.

The first gang to arrive at the location ventilates the surrounding vaults, catch basins, etc., and locates the leak. If on the arrival of the superintendent, the leak is found to be of such magnitude as to establish it as coming from the feeder line, and requires immediate action, steps are taken to reduce the pressure in that section of the line. After the pressure is reduced, digging is started, the emergency truck having gathered enough men for the purpose. The leak is then repaired in the usual way. If the leak is not of such magnitude as to require the shutting down of the line, the leak is repaired as in a low pressure main.

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If the report of the leak is made to the main office, the division shop is notified, the same procedure being carried out as in the previous case.

If the leak is reported to the main office on Sundays, holidays or at night, the division shop is immediately notified. The general superintendent and the superintendent of mains are called, and if the leak is of such size as to warrant their presence, they immediately go to the location. If it is not of sufficient size to need their presence, they keep in touch with the work by telephone. The emergency truck and the telephone are used to gather the men, the leak being handled as in the first case. If the leak occurs at night, temporary repairs are made at that time, permanent repairs being postponed until daylight.

Equipment.

The emergency truck carries all emergency equipment, this including valve keys, shovels, picks, bars, sledges, caulking tools, pulmotor and rescue apparatus, life belts, etc. If it is necessary to procure more tools, the truck readily runs to the shop and brings them out. It also carries electric ditch lights for night work.

Special Conditions Met with in Winter.

Barring frost, the same conditions are met with as at all other times, the same procedure of handling leaks being carried out. The winter brings more broken drip standpipe, services and mains than does the other seasons, but beyond the use of frost wedges, the same apparatus and tools are used as in the other seasons of the year.

Method of Handling Street Leaks in New York City.

Division of Territory.

The borough of Manhattan contains about 1,500 miles of mains and 130,000 services. It is divided into three separate and distinct street department districts, and the division has been so made that each district contains approximately an

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equal mileage of mains and an equal number of services. Each district is under the charge of a superintendent and an assistant. In each district there is a general foreman, who has supervision of all the work. He is provided with an electric automobile, so that he is enabled easily to cover his entire district every day.

Each district is divided into a number of sub-districts, and each sub-district is in charge of a district foreman. The district foreman is responsible to the general foreman for all work performed in his sub-district.

Sources of Leak Complaints.

As a general proposition, leak reports to the office (commonly by telephone) are made by our patrolmen, policemen, or citizens. Immediately on the receipt of such a report the emergency automobile is sent to the location. During regular working hours there is no specially detailed "emergency crew," but the chauffeurs of the emergency automobiles are provided with lists of the locations in their districts at which work is being performed, and on their route to the leak they pick up a foreman and three or four workmen.

Collecting Extra Men.

If on arrival at the leak it is found to be serious, additional men are summoned and despatched in an emergency auto. When the leak has been attended to, the chauffeur of the emergency car, before returning to the garage, telephones the office to ascertain if any further leaks have been reported, and, if there have been, the car proceeds directly to the premises and the necessary repairs are made. During nights and Sundays and holidays each emergency car is assigned to a gang of men under a competent foreman. The chauffeurs have a list of all the workmen in their respective districts, and should a leak be so serious as to require additional men, they may be obtained by summoning them from their homes.

Emergency Automobile.

I enclose several photographs of our emergency cars, together with a list of tools and equipment.

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Fig. 1.

Fig. 2.

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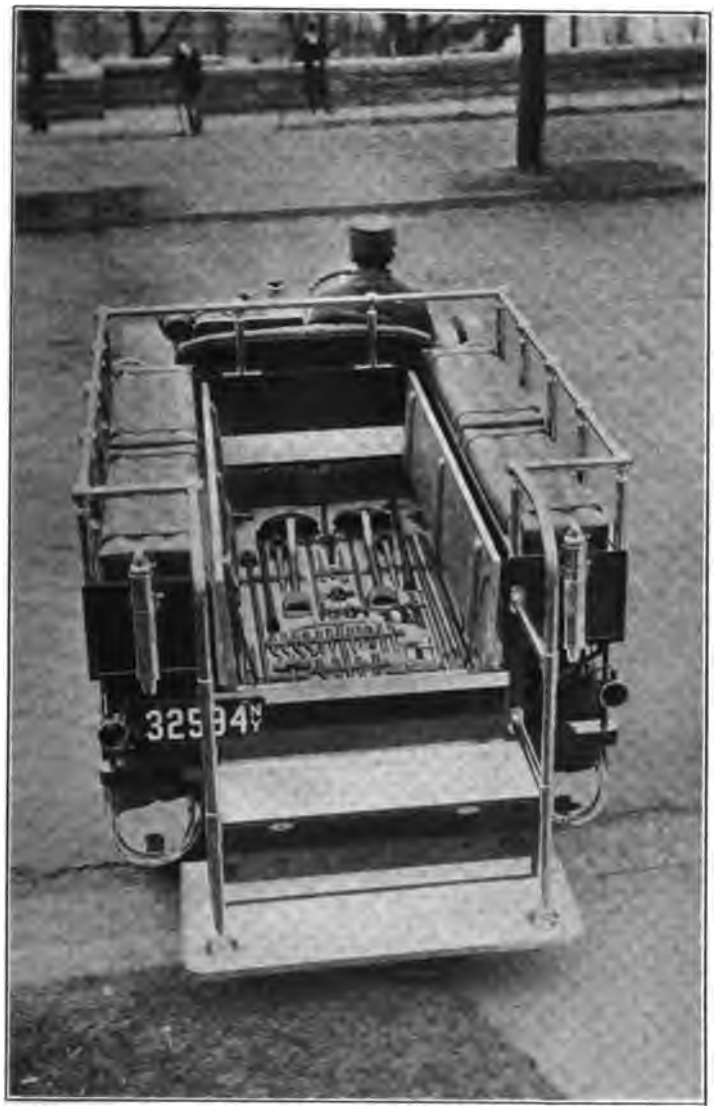

Fig. 3.

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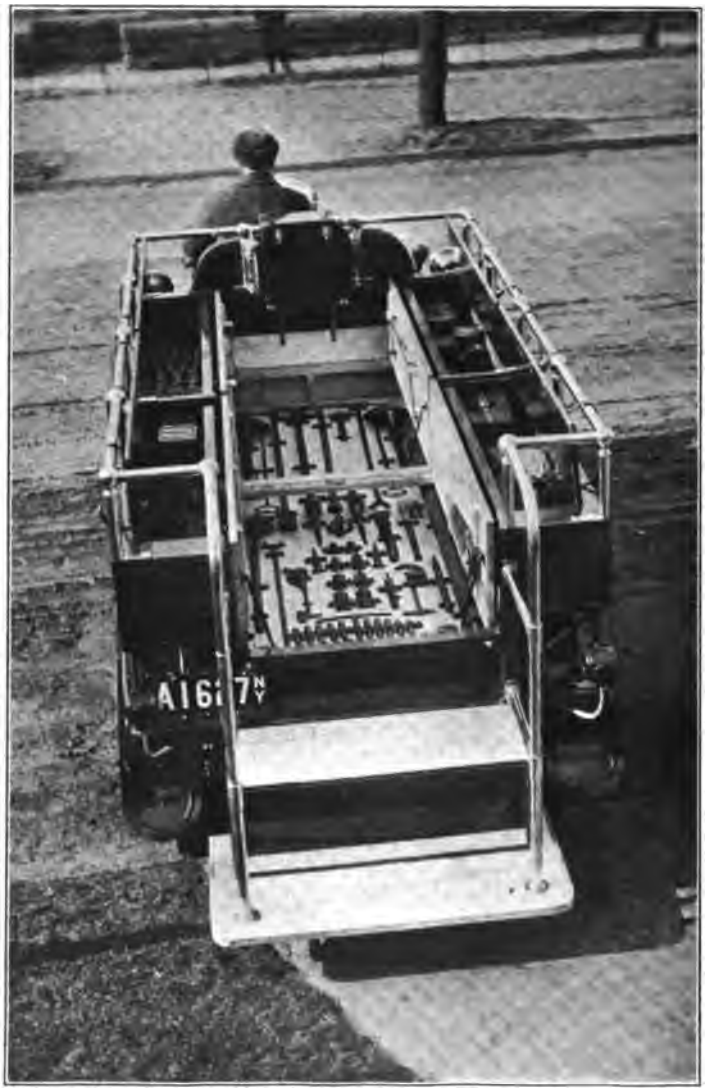

Fig. 4.

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List of Tools and Equipment for Street Lighting Department Emergency Automobiles.

In emergency house	On cars	
2	2	Round shovels
1	1	Chisel bar
0	2	Crow bars
2	2	Picks and handles
0	1	Striking hammer
0	1	Caulking hammer
1	0	Sledge hammer
0	2	Stop cock keys
0	2	Valve keys
0	1	Monkey wrench 10 inches
1	0	" " 18 "
0	1	Stilson " 10 "
0	1	" " 18 "
0	1	" " 24 "
0	3	Cold chisels
0	2	Breaking chisels
2	2	Diamond point chisels
2	2	½ round "
0	1	Bull point "
1	1	Dog "
0	2	Yarning irons
0	3	Stoppers—4 inches
0	3	" 6 "
0	3	" 8 "
0	2	" 10 "
0	2	" 12 "
2	0	" 16 "
2	0	" 20 "
4	0	Steel wedges for frost

2— 3-inch Gas bags
2— 4 " " "
2— 6 " " "
2— 8 " " "
2—10 " " "
2—12 " " "
6— ¾ " Screw plugs
6— ½ " " "
6— ¾ " " "
6—1 " " "
6—1¼ " " "
6—1½ " " "
6—2 " " "
6—¾ " Caps
6—½ " "
6—¾ " "
6—1 " "
6—1¼ " "
6—1½ " "
6—2 " "
5—Caulking tools
1—Tap 1 inch
1— " 1¼ "
1— " 1½ "
1— " 2 "
1—Lamp Rod
1—Trowel
2—Red lanterns
White or red lead
1—Small Johnson's first Aid kit

1—Cross cut hand saw
1—Pair 10-inch pliers
1—Screw driver, 18-inch
1—Squirt oil can with oil
1—Key for drip plugs
1—Sounding rod for drips
2—Subway cover hooks
1—Frame cover for coal chutes
2—Pair rubber gloves
1—Electric lamp, large
1— " " small
2— ¾ inch wood plugs
2—1 " " "
2—1½ " " "
2—2 " " "
2—3 " " "
2—4 " " "
2—6 " " "
2—8 " " "
Soap
Fire clay
Pipe yarn
15-feet 1½-inch rope
Key book of mains
2—Three wheel cutters
⅛ to 1-inch and 1 to 2-inches
⅛ and ¼-inch caps and plugs
Disinfectant for condensation on leaks
Meter locks
1—Draeger rescue apparatus (compl.)
1—Pulmotor

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CONSOLIDATED GAS COMPANY OF NEW YORK.

REPORT OF EMERGENCY DEPARTMENT FOR 24 HOURS ENDING 7.00 A. M., MARCH 28, 1913.

Location.	Reported by	Call received	Car No.	Left yard	Arrived at leak	Returned to yard	Nature of complaint	Remarks
59th St. & 3d Ave.	Consol. Sub. Co.	8.48 A.M.	4	8.49	8.59	9.30	Leak	No leak. Fire caused by Edison burnout.
960 3d Ave.	Janitor	10.10 "	4	10.11	10.20	11.40	"	Shut-off stop-cock supplying gas engine; leak at hose.
56 East 75th St.	Standard	10.25 "	4	3d Ave. 11.04	11.10	11.40	"	Strong smell of gas from street. Will dig.
1435 2d Ave.	111th St. St. Dept.	1.14 P.M.	4	1.15	1.29	2.25	"	Locked stop-cock on cooker on top floor. Leak at thumb cock.
62d St. & 2d Ave.	Consol. Sub. Co.	1.55 "	4	1435 2d Ave. 2.02	2.08	2.25	"	Left man to meet subway people.
866 2d Ave.	Standard fitter	4.11 "	4	4.11.12	4.25	5.54	"	Secured 1½ inch service, corroded in coal chute.
126 West 72d St.	Hill	5.05 "	On foot	5.06	5.16	5.50	"	Locked 30 lt. con. meter in cellar Fixture broken.
340 Columbus Ave.	Respoli Bros.	5.55 "	4	5.55.10	5.58	6.38	"	Secured leaks at outlet cone, 3 lt. con. and inlet cone of 10. lt. con. meters in cellar.
31 West 75th St.	Tanenbaum	5.55 "	4	Col. Ave. 6.10	6.11	6.38	"	Tightened inlet coupling on 20 lt. con. meter in cellar.
N.W. cor. B'way & 21st St.	Edison Co.	7.29 "	5	7.30	7.44	8.35	"	Slight smell coming through electric light post and in manhole on N. W. cor. will hold.
S. E. cor. 20th St. & 4th Ave.	Edison Co.	7.29 "	5	B'way 8.00	8.01	8.35	"	Slight smell coming through electric light post and in manhole on N. E. cor. stuffed ducts; will hold.
310 West 69th. St.	Ciancia	7.34 "	4	7.34.10	7.36	7.50	"	Repaired leak at right and left nipple on cooker in apartment No. 5.

(Signed) PHILIP DUNNE, *Superintendent Emergency Department.*

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Charge to _____ Gas Co

Date _____ 19__ No _____

Location _____

Name _____

Complaint _____

_____

Reported by _____

Work done _____

_____

_____

LABOR IN DAYS.

Rate	Cent.	Mutual	Standard	N A	

MATERIAL USED—W IRON.

Size	Pipe		Bushings	Tees	Caps	Couplings	Cro's	Ells	Nipples	Plugs	Long Threads	Valves	Boxes
	Black	Galv.											

MATERIAL USED—CAST IRON.

Size	Pipe	Bends	Cro's	Tees	Drips	Sleeves	Split Sleeve	Reducers	Caps	Plugs	Lead	Yarn

Completed _____ 19__ _____ Foreman.

Entered on _____ sheet _____ Billed by _____

Entered on "New Service" card _____ Stubbed by _____

Pavement notice sent to G/O _____ By _____

I certify that the above service is "gas tight" and in good condition.

_____ Fitter.

Fig. 5.

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LOCATION OF STREET OPENING.

Street	Side	No	Location	Size of Opening	Dist. from Curb	Kind of Pavement

DESCRIPTION OF SERVICE.

Size of service _____

Service on _____ side

Main is _____ ft. _____ inch

Service is _____ ft. _____ inch

Connected to _____ Gas Co

Badged _____

Size of Main _____ inch

Depth of Main _____

_____ Curb Line

Curb _____ Avenue Street

Drips to _____

Valve _____

TRANSFER OF SERVICES.

Size of Service	Transferred from	Size of Main	Transferred to	Size of Main

Services Cut-off _____

Remarks: _____

Fig. 6.

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Night Emergency Service.

During the hours from 5 P. M. to 9 A. M. the emergency service is under the charge of two night superintendents; and on Sundays and holidays, during the daytime, one of the district superintendents, the assistant general superintendent, or the engineer of the department, is on duty in the main office—in regular rotation.

Daily Reports.

Each day the districts send to the main office a report of the emergency calls on the day preceding, noting thereon the work performed. All the leaks noted on the report are not street leaks, but it is our practice to send out the car in every case of a leak of whatever character.

I enclose a specimen of one of these daily reports.

Supervision of Leak Work.

Now, with respect to supervision of leak work. By means of the daily emergency report the main office is kept well informed of just what leak work is being done. Further, the assistant general superintendent of mains and the engineer of the department cover all the work in progress in the entire city quite thoroughly. Of course it is impossible for them to make a daily inspection of all the work, but the branch superintendents and their assistants cover every job in their respective districts each day, as do also the general foremen; and each evening the general foremen and the district foremen report to the branch office and consult with the district superintendents in regard to their work.

Meeting of Branch Superintendents.

Twice a week a meeting of the branch superintendents, together with the assistant general superintendent and the engineer, is held in the office of the general superintendent of mains, the branch superintendents having with them for discussion reports of the work done in their districts during the preceding week.

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Record of Leak Work.

On every job of whatever character a ticket (see specimen enclosed) is issued and filed. By this means we are able to refer at any time to leak work which has been done at any location.

Winter Work.

With respect to special conditions that confront us during winter work, this proposition generally works out in a different manner each winter. During very severe winter weather, when there is a large amount of frost in the ground, we usually find it necessary to increase the size of our emergency crews and the size of our leak gangs.

Trusting that the foregoing information may be of some service to you in the preparation of your paper for the American Gas Institute, I am

Yours truly,

C. C. SIMPSON,
Asst. Secy. and Gen. Supt. of Mains.

METHOD OF HANDLING STREET LEAKS IN PHILADELPHIA.

Division of Territory.

The distribution area of the City of Philadelphia is divided into five districts. This division is made in order to effect an economic management by providing a base of supplies and operation at various points throughout the city.

It is endeavored to keep the district organizations as similar as is possible, with due regard to local conditions which may more or less greatly affect the methods of accomplishing any desired result.

The details given below relating to various matters concerning "Street Leaks" are those in existence in one of these districts during ordinary winter weather.

ORGANIZATION.

The employees whose sole or partial duty is work concerned with street leaks may be classed as (*a*) executive and (*b*)

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operative. In the first class are the superintendent, or the assistant superintendent, who makes it one of his special duties to supervise the work in this connection, and the foreman of mains and his assistant, whose work is closely in touch with both the office and the street men. When in the office these latter men have charge of directing the movements of the various gangs, and of issuing general instructions as to the disposition of any special cases. When on the street they supervise the work on all of the various jobs and issue instructions to those under their authority. To the executive class may be added the street main clerk whose work is continually in the office. This man, in the absence from the office of the street main foreman, directs the movements of the gangs, and receives reports of any gang foreman. He also audits and files records of completed and uncompleted work; makes out orders giving proper and full information necessary on each new leak job. The "operative" class is comprised of the gang foremen, whose work keeps them continually on the street, and who have direct charge of the "gangs" searching for and repairing leaks, the caulkers and laborers comprising such gangs and any messengers found necessary to convey information from the office to the street.

During the regular working hours, the employees just mentioned attend to the various duties of operation in accordance with the description given later on under "Method of Handling."

At times, not during regular working hours however, the following practices are followed: A description of these will show the organization effected for handling street leaks during such periods.

Any clerk, known as the dispatching clerk, who is on duty in the office at any time outside of the regular hours, is carefully instructed in the administration of the details described in this paper, and in the work of obtaining from the office records, any desired information about our underground structures in an accurate and speedy manner.

On Saturday afternoons of working days, and on days when

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work has been stopped on account of storms, etc., a detail of men whose number is regulated by the conditions of the work and of the weather, is stationed either in the shop or else on a job on the street where they may be communicated with on the telephone. This detail works on any leak received, until a new detail arrives, or until leak is either found or considered safe to leave.

Detail for Holidays and Sundays.

On Sundays and holidays, when any active leak is on hand, a detail similar to that just described is maintained. In case conditions do not justify this, there is placed on duty in the office at least one man familiar with the working on and capable of correctly judging of the seriousness of, any reported street leak. He will make examination and report on any location, new or old, demanding it, and determine on the course to be pursued. Such a man is recruited from the force of most capable caulkers in the district.

Detail for Night Work.

For each night when a regular night leak gang is not working, a detail of not less than five men, including a man capable of acting as foreman, and a caulker, is chosen and the men notified to remain at their respective homes during the entire night. This insures to us a number of men adequate to care for any ordinary leak, and whom we are certain to be able to procure if desired. The number of men from which this detail is chosen is of such a size that each man is detailed for three successive nights every three weeks. No pay is given for this service.

The night complaint men who generally are the first to discover that the source of a leak is in the street are furnished with a list showing men detailed for that night, and after reporting the leak by telephone to the office, this man proceeds at once to notify the detail. The first man notified comes to the shop and, obtaining wagon with tools, proceeds to the job, while the remaining men proceed direct to the job on notification.

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The list just mentioned is maintained by the general foreman of mains. It contains the names of the men with the addresses in such order that the minimum amount of traveling will be necessary in the notification. The men who are capable of acting as watchman on a leak are specially indicated. The list is corrected at least once every month.

In cases where a leak is extraordinarily bad, or more men are needed than on regular detail, immediately after the office is notified, a man is dispatched to notify the men living nearest the shop. These men's addresses are indicated on another list similar to the one just described.

EQUIPMENT.

No attempt will be made to describe in detail the tool equipment. Mention may be made, however, of the "leak drill," which is used instead of a bar in drilling holes to locate leaks, under conditions where it is certain or doubtful that an underground structure which may be damaged is in the line of desired drilling. This tool consists of a 1 inch steel twist drill, 6 inches long, with a threaded shank, to which is attached a 3 foot 4 inch length of ¾ inch wrought iron pipe. A 1 x 1 x ¾ inch tee is screwed to the end of the ¾ inch pipe. An ordinary iron bar slipped through the tee is used as a lever or handle to turn the drill in operation.

An electric lamp for use at night is operated by six dry batteries, giving a total of eight volts and twenty amperes, and a light of about six candle-power which will last about fourteen hours. These batteries, etc., are contained in a wooden box, 11 inches long by 10 inches wide by 9 inches high, with a hinged top cover. The sources of light are two incandescent bulbs each in a heavy socket with reflector and bull's eye cover. One socket is fastened permanently in the end of the containing box, and the other one on a cord about six feet long. The weight of the apparatus is twenty-two pounds.

Medicine, etc., to be used in treating employees or outsiders affected by illuminating gas, is conveniently carried in a leather bag, 8½ x 4¼ x 2 inches. This bag may be easily

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slipped into an overcoat pocket and may be carried by a foreman.

Tools, and if necessary men, are transported on a one-horse wagon, which is specially provided with material to deal with almost any leak emergency. The tool equipment on this wagon is made the subject of special inventories and examinations. The wagon is closed with locked doors at each end, the key to the locks being kept in the office and dispatched when a driver reports that he is about to use the team.

At times when leak work is extraordinarily heavy, or in emergency cases, the automobile used by the superintendent is used to transport tools and men to various locations.

The general foremen and some of the street and gang foremen are each provided with a motorcycle. Foremen not having motorcycles are provided with bicycles and an extra bicycle is provided for each leak gang.

METHOD OF HANDLING.

By "Method of Handling" is meant the manner in which the report is treated after becoming known to the office.

When the distribution office receives notice of a street leak, which notification is usually by telephone, the office man obtains from the person reporting, the necessary details as to the extent of the leak, the possibility of good ventilation, an idea of the general surroundings and information concerning persons claiming to have been affected by the gas. From this information he judges as to what should be the immediate disposition of the leak. This is made by considering the following points:

An odor is usually reported as strong, slight or doubtful.

If any leak, regardless of its location, is reported as strong, the man reporting it is ordered, except in cases where it is imperative to use him for another purpose, to stay on the job until relieved by another man or by the leak gang. The location where the odor is noticeable, *i. e.*, in the cellar of a building, at one stop box only, or at more than one stop box, etc., serves as a guide to the office man in sending either a gang to

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work the leak or a street foreman to decide if immediate work may be delayed.

An odor reported as strong in cellar or cellars, and at stop and drain boxes at curb, indicating probably a broken main or other extensive leak, would be considered a case which should be worked at once, and a gang is dispatched as soon as possible.

Any strong odor evident at the top of a lamp post or in one gas stop box only, indicating probably a break at the bottom of the post or in the service at the cock, is classed as a location which is to be visited by a street foreman who determines definitely whether the leak should be watched or worked.

When the odor is reported as slight, and if ventilation will remove it, the man reporting is instructed to proceed with his work, and the location is turned over to a street foreman who makes a visit within an hour or two to decide on the immediate course to be pursued. This refers particularly to odors in buildings; however, every slight odor reported is soon visited by one of these foremen.

In cases where the odor is reported as doubtful, an examination is to be made by a street foreman, who will decide either that the odor is not that of illuminating gas, or in order to make this decision will order a gang to the job for a thorough examination of manholes and sewers.

Course of Leak Order.

On receipt of a street leak, the street main clerk, or if not during this man's working hours, the man designated, fills in a form known as a "Street Leak Order." On this form, which is 8 x 5 inches, is placed the date and time of report, name of man reporting, and information concerning size and location of gas mains, etc. A space is provided for a sketch of limited size to aid the leak gang foreman in cases where underground conditions are complicated. In addition to this order there is originated a 3 x 5 inch card bearing the address and date and provided with a column in which to enter the results of conditions found on each visit. This card is kept in the office

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and is posted as reports on this leak are made. If the leak needs further examinations, or has been temporarily repaired, this card will indicate what is further to be done. The card is filed behind a date marker and thus the examinations due any day are automatically brought to light at the proper time. Examinations at any locations are made according to the following rules:

When a "slight odor" location is not being worked on account of more urgent leaks, an examination is made at least once every day until leak has been worked on and found.

Supplementary Examination of Locality.

After a leak has been found and stopped, it should not be assumed that the complaint is entirely remedied, as there may be another leak that is the cause of the complaint. Therefore an examination is made the day following that of the repair (temporary or permanent) to ascertain if conditions have been remedied. If an odor exists, active work should be resumed as soon as possible. Even if the complaint seems entirely remedied, a second examination is made one week after the first.

Such examinations are omitted in cases where cause of a leak is definitely known, such as broken lamp post, service cock broken by fitter, or pick hole in gas pipe.

Examinations as above are made also in cases where "no odor" is present on first visit.

After the two records above mentioned have been originated, the next step of the office is to "dispatch the leak."

If it has been decided that it is necessary to work immediately, a gang is notified by 'phone, by messenger, or by one of the foremen who are in frequent communication with the office. The telephone is put to the most extensive use. Whenever a gang is working where a "pay station" or store is near at hand, the foreman of the gang on his arrival on the job will notify the office of this number. In emergency cases, when such a 'phone is not obtainable, the office will obtain from the telephone company the location of the 'phone nearest

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the gang desired, and calling, will ask the person answering, most likely a consumer, if he will be kind enough to ask our foreman who is working in the street to communicate at once with the office.

Claim Department Notified.

If it is unnecessary to work the leak at once, it is held and given to a street foreman to make an examination. If the report of the leak contains the information that any person claims to have been affected by the gas, the next step taken by the office is in all especially serious cases to notify the Claim Department, or its representative, at once, regardless of the time of day. Notification to this department, if not during regular working hours, is delayed in cases that are not serious, but in any case, one of the company's physicians is requested immediately to visit the persons affected.

Street Leak Progress Report.

For each visit to a leak location, a "Street Leak Progress Report" is filled out by the man making the examination. This report shows time of day and history of conditions found and work done. If the work on a leak is continued without interruption over a period of more than one day, a report is made for each day, and if the foreman on a job is replaced during the progress of the work, each man makes a report of the work done by him. Reports for work done any day should be in the office by the end of that day. Any leak found is reported at once by telephone. Each report is carefully audited to see that it contains all pertinent information, and is filed daily so that the complete history of any leak is available.

Working Conditions.

During ordinary winter weather no regular night gang is worked. During such times as a night gang is necessary its size is about one-third that of the day force.

Any overtime hours during especially strenuous periods should be reduced as much as possible. For short stretches most men can work sixteen to eighteen hours a day, and if

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necessary, twenty-four hour periods can be occasionally worked.

During such periods, the varied length of the working day can be made to result in gangs reporting at intervals throughout the day, and this will allow greater ease and speed of dispatching leaks received shortly before such a gang is expected.

In case a lack of foremen is a troublesome condition, other men who with a little instruction will prove capable, should be selected from the best employees of the fitting department. Even though these men are unfamiliar with digging and street conditions, they are far preferable to new men trained in digging work but unfamiliar with gas and its effects.

In closing, it may be said that the main points in efficiently organizing for and handling street leaks, are common sense and thoroughness, together with the highest regard for safety always.

H. B. ANDERSEN,
Supt. of City District
Philadelphia Gas Works.

METHOD OF HANDLING STREET LEAKS PERTAINING TO ST. PAUL.

Course of Leak Order.

Ordinarily a leak complaint comes in by telephone. The telephone operator therefore gets the first information, and if the complaint is reported as being very serious the call is put directly on the distribution superintendent's line. Ordinarily complaints are written up by the complaint clerk and a regular order put in the chute communicating with the shop foreman's office. Of course, the complaint clerk is supposed to obtain all information possible, such as the name of the party reporting, nature of the leak, if in house, basement or street, how long it has been noticed, and particular attention to getting the correct address. If reported as a street leak the shop foreman telephones the superintendent's office giving the address and also states if he can get a man there promptly.

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Generally he is expected to send a man on all leak complaints for the purpose of safe-guarding persons and property from injury. He ventilates premises, cautions persons, and maintains guard if necessary until the repair crew is on the job.

Prompt service of the fitting department is insured as follows: First, a motorcycle is maintained by the department for urgent complaint and leak orders. Second, each fitter's duplicate orders, on which he is working, are kept in labeled files so that the shop foreman knows in just what part of town each fitter is at work at any time during the day. In case the motorcycle man is out, or the machine is not in commission, or the complaint is a long way from the office, by a liberal use of telephones, of parties leaving orders, the fitter in the vicinity of the leak complaint can be communicated with and sent to care for the leak at once.

If for any reason the shop foreman cannot care for the complaint promptly he notifies the superintendent's office and a street foreman or someone from the superintendent's office is sent out on the order. The reason for notifying the superintendent's office when a leak order is first received by the shop foreman is to enable his office to get in touch with a street foreman pending a report from the fitter sent to investigate the complaint.

Division of Territory.

We have divided our city into two divisions, a general service and repair foreman with five or six crews being placed in each division. Each general foreman reports or telephones early each morning the schedule of each crew for the following 24 hours. He also telephones or reports to the office two or three times each day for special orders or complaints.

Organization.

When a fitter sent on a complaint reports by telephone that immediate attention is necessary and what the probable extent of the leak is, we have either arranged for reaching the general foreman or can give the fitter the location of the nearest crew

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and he is sent to notify them of the leak. These crews consist of from 4 to 6 men and always have one experienced gas man capable of handling ordinary leaks, such as broken or leaking services, cracked mains, bad joints, etc. The general foreman is also notified by the superintendent's office as soon as possible so he can get on the job and assume the responsibility. To prevent any friction such as the crew boss or foreman refusing to look after leak promptly when notified by the shop fitter, we have given each crew foreman orders to telephone to the superintendent's office whenever anyone tells him of a leak or wants him to do work not authorized by his general foreman.

Equipment.

Each service box carries a set of caulking irons, one or two bars of ordinary laundry soap and such small supplies as are generally necessary for ordinary street leaks.

Night Work.

A complaint man with motorcycle is kept on duty nights and Sundays. In case of street leak he telephones the superintendent's house or the assistant from the premises or vicinity, making report of the seriousness of the leak. He is given instructions what to do pending the arrival of the repair crew.

Both general foremen have telephones and each has a list of about half a dozen men quickly accessible by telephone or messenger, so that a crew can be assembled within a reasonably short time.

The teaming contractor has a telephone, and a wagon and driver can be secured at any time.

Picks and shovels are available at the office or at the nearest service box to the leak.

Time and one-half is allowed for Sunday work and night work for fitters and laborers. General foremen are on a monthly basis.

We have had no occasion to use other than lanterns or pocket electric torches on our work.

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A "servus helmet" has been kept in the department for the past three or four years, but has only been used once or twice.

During the past few years leaks of any magnitude have been very rare.

In the business section where traffic is heavy week days, night work is sometimes desirable. Ordinarily, however, it has not been our practice to work nights unless imperative, due to lack of intelligent effort and the extra hazard. Sunday work on the other hand is generally desirable both from the absence of ordinary street traffic and also because we can generally get more skilled help when our regular work is not going on.

Special equipment or supplies can be secured at the office or from the storehouse. The storekeeper or the superintendent can be reached by telephone, both having keys for the storeroom.

Winter Work.

In the cold months of the year the only difference is in securing crews. We generally find employment for some of the older and more experienced street men in the meter repair shop, and fitting shop overhauling stock and tools and doing general repair work. It is therefore an easy matter to make up one or two crews at any time during working hours, and if necessary we have the nucleus for half a dozen crews and can pick up what extra labor is needed with little delay. Night and Sunday complaints are handled the same as in the summer months.

Owing to the slow progress in digging and the increased difficulty of locating the source of a street leak when the ground is frozen, our rule is always to ventilate the premises and sink one or more holes near the foundation walls and intercept the current of gas entering the building. This must be done before all other work unless sufficient help is at hand to make excavation for the repair of the leak at the same time.

Drilling over the mains and services is generally done to locate the leak, but it is frequently generally necessary to dig

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test holes 2 or 3 feet below the mains to intercept the currents of gas travelling in the ground.

The superintendent's office is always kept advised regarding each leak. If a leak is not repaired during the day the superintendent is notified so that proper precautions or instructions can be issued to cover same.

In case the leak has caused any damage or anyone claims to have been affected in any way from the leak or if the complaint man thinks there is any chance of claim being made of injury at a later time, someone is sent from the superintendent's office to thoroughly investigate and make a written report, and in that way endeavor to forestall any unjustified claims.

Each repair order issued to the foreman must be filled out stating the nature of the leak and repairs made, the labor and material required and the probable cause of the leak, also giving a working drawing of the exact location.

In the winter time it is generally necessary to call back two or three times after a leak is repaired to see that the dead gas held in the ground does not seep into the adjoining premises, causing inconvenience to the occupants. It is often necessary to maintain vent holes outside of the foundations of the buildings for days and sometimes weeks after the leak is repaired.

MR. WALTON FORSTALL (Philadelphia): The author does not overstate the paramount importance of the prompt handling of street leaks. Not only to prevent injury to the innocent consumer, but also to protect itself from the unjust claims of the fakir and his shyster lawyer, must the gas company be ever prepared to investigate immediately every leak complaint, and have forthcoming the evidence of such prompt response when it may be needed to combat false damage claims. While it is true that the most economical equipment for this work for a larger company may involve automobiles and other emergency motor vehicles, it is fortunately also true, as noted by the author, that the small companies can provide proper emergency equipment at an expense well within their means.

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As a matter of fact, Philadelphia has never found it necessary, in connection with its street leak work, to use a special emergency motor vehicle. In some cases, the first call is looked after by a motor cycle man, and at times the automobiles of the superintendents might be utilized, but, in general, a complaint man, on a bicycle, and the assembling of the street men by telephone and trolley car, has, in combination with the system described by Mr. Anderson, proved adequate.

THE CHAIRMAN: Gentlemen, Mr. Whittaker has touched upon a very important subject, and I trust we may now have a very full discussion of his paper.

MR. C. H. WARING (Kansas City): In connection with this, I want to say that we have a "Service Cart" equipped with the necessary tools and fittings to repair a leak of any kind, either a broken main or broken service. The leak is first looked up by an inspector and if he decides it is in the street he telephones to the distribution shop and this cart is hauled out to the leak. The laborers are notified and either are taken to the job by automobile or trolley car. This service cart is also equipped with a storage battery and a small light for night work.

MR. H. H. GANSER (Norristown, Pa.): This report is so interesting and so highly instructive that I can scarcely add anything of value, but I regret that it did not make reference to the small gas companies. The small gas companies are in quite a predicament, particularly in the winter months as to the handling of leaks successfully, particularly street leaks, and it is quite a difficult matter to have a good organization to handle these leaks effectively and quickly. I want to call attention to the necessity of having the men who are going to do this work (search for leaks) to be thoroughly familiar with the location of main services, to get the information from the maps and charts, because we always find it exasperating to dig down on the main and find it is not within 2 feet of the leak.

I might add to those who have steam heating appliances

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in their town that where a leak occurs in a street main I do not have to tell them what trouble they are to expect having the leak following the casing, originating close to the brick or record box, and then following the casing into the premises of a consumer. If there is any time a consumer can get real irritable that is one of the occasions, because gas traveling by a street heating main does not smell any longer like gas. I don't know what it does smell like, but it is such that the consumer is ready to put up a very disagreeable fight. And I have found in cases of that kind a very effective remedy, and that is in using Rufus cement to remove the asbestos flanging and asbestos paper collar that is around the casing in the consumer's premises, and filling it with Rufus cement which will stay there an indefinite length of time and immediately relieves the premises from all odors. There is another way of relieving it from the steam mains, at the same time venting the entire street, but the owners of the steam heating company very often object, and rightly too, to using this method, and it is only because we operate a steam plant that we resort to it. That is by digging down on the steam main and boring through the casing and putting in a 2-inch pipe. It very readily sets up the circulation there that draws it out immediately, but great care should be taken when this is done to be sure and plug that hole carefully, or at least notify the steam company what has been done, so that surface water cannot get in on the steam.

THE CHAIRMAN: Mr. Gould, were you going to discuss this paper?

MR. J. A. GOULD (Boston): I think it is hardly necessary for me to describe our method of handling leaks in Boston, as a letter from me to the author of this paper describing our methods is incorporated in Mr. Wittaker's paper. This in many respects is a local question. Different cities and different parts of the same city may require different organizations, but whatever organization we find necessary to properly protect any district, it is absolutely necessary should be kept up to its highest efficiency.

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MR. THEODORE BUNKER (Paterson, N. J.): Mr. Chairman, when I was asked to take part in this discussion I found after reading the paper it was very difficult to add anything along the lines of the paper. I have written and put in for a matter of record a discussion which will carry the matter into the question of the organization of handling and quickly getting the leak when you arrive at the property.

The description of the organization and equipment of the four (4) large companies seem to thoroughly cover the subject in detail. Small companies could organize and equip along the same lines without unduly increasing expense. The feature of the handling of street main leaks which does not seem to have been thoroughly covered in any of the papers, but which is of the utmost importance in safety and economy is the plan of procedure with reference to locating the leak itself. A leak reported as a street leak may be in the house piping, in the meter, in the service or in the main. Most systems of organization provide in the case of a reported leak that a fitter should go to the house first to determine the nature of the leak. He should be instructed to put a water gauge air test of say 3 inches on the house piping to determine if there is any leak in the system, put a similar test on the meter to determine leakage at this point and test with soap-suds the service fittings up to the meter inlet. If no leak develops at these points the fitter is immediately in position to say definitely that the leak should be turned over to a street gang. The water gauge test is a very delicate one and will promptly indicate the existence of even a small leak. It is not safe to assume if a leak is discovered at any of these points that there is not a street leak.

Upon the arrival of a main gang an opening is usually made to immediately relieve the gassy smell in the house. This opening is usually made at the building line where the service enters. A more efficient method is to open the street immediately over the service tap, because this opening can be used for testing the service with a water gauge. The method of quickly testing the service where the main con-

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nection begins with a tee is to shut the meter cock, put a rubber service plug (without the tee handle) in the service tee at the main and cover the straight iron handle of the service plug with a nipple and cap. By taking the plug out of the tee in the cellar and attaching a "U" gauge, an air test can be put on which will at once determine whether the service leaks.

By the three (3) tests mentioned above the leak can be definitely eliminated from the house, the meter and the service, and the work of locating be confined to the main itself. I believe that gas companies in general will profit by including these three (3) tests as part of the organization of handling each and every street leak. The cost is moderate and the results sure.

We are apt to trust too much to the judgment of experienced employees in this work of locating leaks. While not overlooking the value of experienced leak men, yet it is certain in that no experience can be better than a positive method of testing of certain portions of the system as noted above. In leaks that are difficult to find in the main system, by isolating a section of main with two bags at each end separated by water and feeding gas to this section through a meter, any leak will be shown and its size indicated by the meter reading. We have cheap and effective means of definitely determining whether certain sections of the system leak, but as a rule instructions to fitters and street men do not call for carrying out these tests. In order to make these tests of definite value and be sure that they are regularly carried out, the card system should include a list of these tests to be actually reported upon in each leak.

THE CHAIRMAN: Any further discussion, gentlemen. I wonder if Mr. Ellis has anything to say.

MR. W. ELLIS: I don't believe I can add anything new or interesting.

THE CHAIRMAN: Once more, gentlemen, may I ask is there anything further in the way of discussion on this paper?

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If not we will ask Mr. Forstall if he has anything to say in closing the discussion.

MR. WALTON FORSTALL: Mr. Chairman, I think that the value of this paper is very largely an educational one. As I stated about one of the other papers there may be a certain number of members of the Institute who have not thought as long on the subject of street leaks as they ought to. The real point is street leaks sometimes means loss of life, and that is most important. Next comes the financial loss. Otherwise, the subject would not be as important as it is. Our company lost five lives in one accident, the only fatal case we ever had, and we are very glad to feel it was absolutely no fault of our own.

THE CHAIRMAN: The chair desires at this time to thank the members of the Institute who have done so much to make Section B a success by lending their presence in this room, by preparing and reading discussion of the papers. It has been a pleasure indeed to preside over the meeting, and I am very heartily grateful to you for your assistance which you rendered in making this section of the meeting such a great success. If there is nothing further we will stand adjourned.

MR. C. PILZ (New York): I move a vote of thanks to the chair for the extremely clever and expeditious way in which this meeting was handled.

Motion duly seconded and carried unanimously.

Thereupon at 4:20 P. M. the meeting was adjourned.

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DESIGN OF SURFACE COMBUSTION APPLIANCES.

LECTURE DELIVERED BY DR. CHARLES E. LUCKE IN THE AUDITORIUM OF THE JEFFERSON HOTEL, RICHMOND, VIRGINIA, ON TUESDAY EVENING, OCTOBER 14, 1913, AT 8:15 P. M.

Manufactured gaseous fuel is and always will be more costly per unit of heat carried than natural fuel, and yet may yield cheaper and better service, cheaper if the process and apparatus used for the combustion of the gas is efficient enough, and better if it is so designed as to liberate the heat in a sufficiently more available form. It is this fact that justifies the general interest now shown in the process that has been termed *surface combustion*, which promises both cheaper and better gas service, the realization of which depends on the accumulation of much new data for the design of apparatus of commercial form. Some of this information has been worked out, and commercial apparatus of one or two classes designed therefrom. The process of development that has resulted in the establishment of surface combustion on an engineering basis whereby apparatus can now be designed to meet specific conditions is reported briefly in this paper.

The new process assumes that gas to be burned should be supplied with no more air than will supply the required amount of oxygen for the combustion reaction, and that the air and gas should be thoroughly mixed previous to combustion, so that the reaction may take place instantly, once the ignition temperature is reached. Excess air is regarded as not only useless but harmful because of its heat absorption, preventing the attainment of the highest temperatures so desirable when the heat of combustion is to be communicated to other bodies, and carrying away as flue heat, quantities that would otherwise be of use. Premixture is regarded as desirable because thereby each particle of fuel may be brought positively into intimate contact with its required oxygen before it is needed, instead of depending on the accidental dissipation of the products formed on the edge of a flame jet, before the central core of gas can

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secure air from a surrounding and supporting atmosphere. This premixture, in conjunction with suitable proportioning, prevents the escape of unburned fuel in any form. Thus premixture of air and gas in combining proportions, at once insure protection against two important sources of loss in combustion: that due to excess air and that due to incomplete combustion. As an incidental accompaniment another advantage of no less importance follows, and that is development of the heat of combustion in a form more available for absorption by the bodies to be heated, and for the heating of which the gas is burned. Heat will be absorbed most readily from a fire when the temperature of the gases leaving the fire are most hot and when the fire zone is most radiant. All heat absorbed from a fire by direct contact of the absorber with the hot gaseous products is absorbed at a rate directly proportional to the excess of the temperature of the gases over that of the absorber, so the hotter these gases are, the more heat will a given absorbing surface take up, other things being equal. Heat is, however, much more rapidly absorbed by bodies when the source is radiant, because radiant heat readily pierces the insulating dead gas films adhering to the surface of the absorber and resisting by its low thermal conductivity all transmission from passing hot gas streams. The superior transmitting value of radiant heat has been well known as long as physicists have studied the sun's rays, but it has been lacking in most, though not all gas burners because of the very low radiant value of hot gases as compared with solid bodies at the same temperature. The premixture of the gas and its supporting air make it very easy to secure a large amount of the heat of combustion in a radiant form, because the combustion, being entirely independent of any atmosphere into which the products may be discharged, can be carried on behind layers of solid granules, in the crevices between them, in holes in solid plates, or behind solid plates of any convenient form, all of which, attaining the temperature of the gaseous products of combustion, radiate heat at a rate immensely superior to that of the gases themselves.

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With all these prospective advantages in the direction of superior efficiency of gas burning apparatus, when the gas is supplied in the form of a premixture with its air in combining proportions over all other modes of supply, the question naturally arises as to why this has not been more commonly practiced, and once the idea is advanced, why there should be any delay in at once proceeding to the design of suitable appliances. The answer is to be found in the peculiar physical properties possessed by such mixtures over those now commonly in use, which make them difficult to control in the absence of detailed knowledge of these characteristic properties. In fact, without such knowledge, design of apparatus is quite impossible and it becomes feasible just in proportion as information of the needed sort is established by experimental research.

The fundamental peculiarity of such mixtures that renders control difficult is the property of self-propagation of flame through them, bringing them into the class of things commonly termed explosive. As all the mixture is in a condition suitable for combustion, once the ignition temperature is reached, it naturally follows that as the combustion temperature is much in excess of that of ignition, the burning of however minute a quantity of mixture at a point of ignition, will promptly heat neighboring layers of mixture far above their ignition temperature, so that the flame will of itself proceed through the whole mixture mass if it be isolated in a chamber. The only way such a self-propagation could be stopped is by preventing the heating of a fresh layer by the combustion of its neighbor, such prevention taking the form of a heat absorption by some solid screen at a rate great enough to permit the screen to take up the heat of combustion of all the mixture in contact with one side without itself becoming hot enough to warm the mixture on its other side to the ignition point. It is easy to make such flame interrupting screens that will stop the propagation of flame through an explosive mixture once or twice, but difficult or impracticable to make them so as to be able to continue to do so indefinitely. With the exception

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of the internal combustion gas engine, gas burning apparatus requires a continuous burning of gas as supplied in a definite place termed the burner or furnace. When explosive gaseous mixtures are supplied to such continuous fires, the property of self-propagation operates to defeat localization of the combustion unless specific means are provided in the design of the structure to make the treatment of the mixture conform to its physical properties, in which case the combustion can be more definitely localized than otherwise. For any given mixture there is a definite normal rate of propagation which may be equal to, less or greater than the velocity of flow of the mixture into the fire, and it is clear that localization of combustion will depend primarily on the relation of these two rates, that of flame propagation and that of flow. If they are equal, that is, if the flame can burn back toward the source of mixture supply, just as fast as but no faster than the mixture reaches the flame, then will the flame remain fixed or be definitely localized. In fact, the above is the primary condition for localization of the combustion of explosive mixtures, because otherwise the flame would travel back to the source of supply or be blown out by the physical pushing away the faster flowing fresh stream of mixture. Of course, localization may also be secured if the mixture be fed through a flame interrupting partition at a flow rate inferior to that of propagation, in which case the localization takes place on the face of the partition, which must, of course, have a large capacity for heat absorption indefinitely, which means in effect, that it must be able to dissipate or transmit to some other body the amount of heat it is receiving, or otherwise it would rise in temperature to the point where it, by igniting the mixture on the supply side, ceases to be an interrupter.

Mixtures of the sort that seem best from the standpoint of efficiency of apparatus, having this explosive property, require a special treatment to permit of their use in commercial apparatus, which special treatment has for its first object the definite localization of the flame. The means employed must, moreover, be so positive as to be unaffected by long continued

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operation, that is, the localization must be permanent. There are, however, still other conditions to be met, such as control of rate of combustion per square foot of fire or per cubic foot of furnace, a cook stove requiring a low and a crucible furnace a high rate, and as such mixtures have what might be called a natural rate corresponding to the normal rate of propagation, it is clear that specific means must be available for burning slower or faster per square foot of gas stream cross section. Furthermore, any one burner or furnace designed for some definite or normal rate of combustion or gas consumption, would be valueless commercially unless it would operate quite as positively at a wide range of variation, both above and below that normal rate. In other words, localization of the flame must not only be positive, and any desired rate of combustion be attainable by design, but in addition, hand or automatic interference with the designed rate of consumption must not in any way interfere with the localization. In some cases it is desirable that the burner be capable of reaching its normal or steady working state in a short time, such for example, is the case with a domestic cook stove burner, while on the other hand a slow heating corresponding to a large heat storage in the furnace is necessary when articles are constantly being thrust in to be heated and then drawn out, without too much change of temperature in the furnace, so control of heat capacity of the burner must be available. Finally there must be provided mechanical means for making the desired mixtures and for maintaining the desired proportions sufficiently, means so simple and automatic as to require no more skill or attention on the part of the operator than appliances now in use.

Accordingly, this review of the work of development of the first commercial surface combustion appliances is divided into the following divisions:

1. Localization of combustion zone, initially on starting cold apparatus and its permanency with the attainment of the steady state of the fire.

2. Control of rate of combustion per square foot of bed or hearth for high rates and low.

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3. Control and adjustment of radiating surface.
4. Auxiliary apparatus.
5. Efficiency of surface combustion appliances.

The experimental work here reported has all been done by or under the direction of the writer, partly in his laboratory at Columbia University, but largely in the laboratory of the Gas & Oil Combustion Co. in the Chemists Building. Acknowledgement is freely made of the contributions of the laboratory staff, headed by Mr. Frank Creelman and including Messrs. E. J. Allen, H. L. Ocumpaugh, F. A. Wegener, W. B. Eddison and Prof. E. J. Hall of Columbia.

Only the results of New York City illuminating gas are here reported, though work has been done with other fuels, and satisfactory results obtained that permit the statement that all fuels in the gaseous or liquid form are equally available to the process.

Localization of Combustion Zone.—Reasoning from the fact that the flame cap or surface over which combustion is proceeding, will be steady in location only when the velocity of the mixture approaching it is equal to rate of flame propagation for such a mixture, the first step in the design of practicable apparatus is the formation of gas passages of suitably changing area, since the velocity of gas flow for small changes of pressure will vary inversely as the cross section of the flow path. The mixture should approach the fire zone through a small tube or orifice at a rate greater than the normal velocity of flame, but immediately beyond there should be an enlargement of the cross section of the passage to permit of velocity reduction, which, if carried far enough, will finally cause flow velocity to drop to equality with flame velocity, which was, at the point of entrance, in excess. Mechanical constructions that will permit of this can be designed in almost endless variety, many of them equally good, but for the best results certain precautions must be observed, notably, first, the tendency for a gas jet escaping from an orifice under pressure to resist side-

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wise expansion so that even if the passage offers an increasing area for flow, the gas stream may not fill it unless forced to do so by baffles or their equivalent, and secondly, the tendency for free jets flowing through a gaseous atmosphere of products of combustion, for example, to entrain or diffuse with that atmosphere at the edges, becoming so dilute as to not burn properly, if at all.

Perhaps the simplest apparatus would be a very narrow angle conical passage to which mixture is fed at the smaller end; the stream expanding sidewise to always fill the cone would reduce in velocity and permit of the location of a combustion surface quite definitely. In time, such a conical tube would get hot, in fact at the section where the flame surface located it would become incandescent almost immediately if of refractory material, or melt off if of metal, and, of course, the narrower section along which the fresh mixture approaches would heat by conduction and warm the feeding gas. This mixture heating would tend to increase flow velocity and push away the flame surface if another counter influence did not prevent it—the increase of flame propagation rate, which is partly due to rise of mixture temperature and partly to the accelerating effect of the hot solid walls. This counter influence accelerating combustion and drawing the flame surface back against the supply current is really stronger than the pushing away effect of velocity increase due to expansion of the stream by heating. Such cones are not for most purposes good forms for the purpose because of the limit imposed on adjustment of rate of supply which if varied very much would cause a blow off or a back flash of the flame, unless the cones were extremely long. When, however, a steady rate apparatus is needed and flow is fixed, there may be just enough sidewise expansion of the jet issuing from a simple hole in a plate to locate the flame, but the practical uses of such apparatus are very small.

To meet the needs of every-day service there must be a more positive localization of the combustion surface, insensible to variation of mixture pressure or flow rate, over a wide

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though definite service range, and this requires specific provision for stream baffling so that the gas stream will increase in cross section rapidly beyond the supply point of minimum area and safe maximum flow velocity. Perhaps the simplest of these flame spreaders is a plate over the hole through which mixture escapes as in Fig. 1. By placing the baffle away from the plate, carrying the orifice, a distance equal to one-quarter of

Fig. 1.

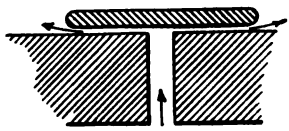


Fig. 2.

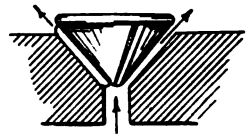


Fig. 3.

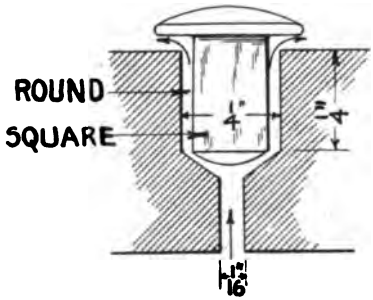
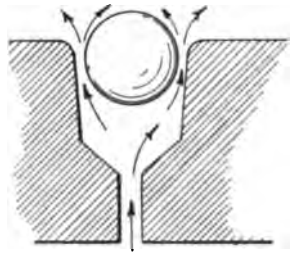


Fig. 4.



Figs. 1 to 4.—Means for velocity reduction, to control localization of combustion surface.

the diameter of the orifice, the stream direction will be turned through a right angle without changing the flow velocity until the stream moves out under the plate beyond the hole, when, of course, the velocity will be reduced inversely as the diameter of the circle which the gas occupies at any one time. With a hole 1/16 of an inch in diameter, a plate spaced 1/64 of an inch away could reduce flow velocity when cold to one-eighth of its entrance value if the plate were ½ inch in diameter.

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This would permit of an eight-fold change in the rate of flow when cold, keeping the flame surface always under the plate, and give to the flame surface the form of a short cylinder. Such a construction offers some difficulties, as in operation both plate and hearth would get very hot and unequally so. Starting at the center the plate would remain dark, becoming incandescent from the flame zone out to the edge which would crack most plates refractory enough to resist fusion, even if a practical way of making such plates and holding them in position, were available. An easier construction is shown in Fig. 2, in which a solid (alundum cement) cone with three small ribs is placed in a counterbore of the feed hole. This is self-locating when in the position shown, but not otherwise, Still another form that holds the baffle definitely against side movement is shown in Fig. 3, in which the baffle is shaped somewhat like a mushroom with a square section stem which fits loosely in an enlargement of the feed hole, so that the flow area does not change materially until the escaping mixture strikes the underside of the head and is deflected outward. The dimensions given are those used on some that gave good service with mixture pressures up to three inches of water, though a little troublesome to make and apt to break if not gently handled. The most permanent form of this class of molded baffles is the refractory ball in a conical hole as shown in Fig. 4, and it is interesting to note that the ball, remaining suspended in the jet and keeping by reason of its weight a constant velocity of the jet around it, insures that the flame locate above it, keeping it cooler than otherwise, so that fire clay balls have remained uninjured whereas the same clay a short distance above readily fuses. The physical action is here slightly different than in the previous cases, the escaping mixture forming an expanding and velocity reducing jet of ring form between the ball and its seat.

While in the constructions shown as typical, localization of the combustion surface is definite and mixtures may be burned in combining proportions, all fail to produce the uniform in-

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candescence, that is easily obtainable otherwise with such mixtures, though, of course, a series of such baffles spaced uniformly approach this result, but instead of giving a uniform glow have a spotty appearance from black to truly incandescent. It is found, however, that a porous screen of any sort placed in the path of the escaping gases, will get uniformly hot and such screens have been used of three sorts, first—a perforated plate of metal, made of one of the non-oxidizable alloys such as are used in electric heaters; second—a layer of granulated refractory material; and third—a diaphragm of bonded granular material, the most satisfactory of which were made of Norton alundum. Of course, the less mass given to the screen the more rapidly it reaches incandescence initially, and in this respect the metal screen is best. One of these placed 3/8 inch over a hearth 4½ inches diameter supplied with 35 holes each 1/16 inch diameter and ¼ inch ball baffles, heated in six seconds, while diaphragms thick enough to be mechanically strong may take five minutes, though, of course, the latter are more permanent. With the same arrangements, except that the mushroom baffles were used instead, the following consumptions of gas were measured at the corresponding pressures and gave a steady dull red at the lowest rate and correspondingly brighter at the higher rates; 7.25, 9.1, 10.9 12.2, and 14.2 cubic feet of gas per hour at 1.00, 1.5, 2.0, 2.5, and 3.0 inches of water pressure. A similar set of mushroom baffles set in a vertical hearth and having a screen of crushed fused silica ⅝ inch deep of size between 20/64 inch and 13/64 inch, held in place by a second screen of wire mesh, heated to incandescence in 3½ minutes at a supply pressure of 2 inches of water.

All the previously described baffling means intended to assist the spreading of the mixture stream beyond the point of high velocity supply, and many others of the same class, are used to counteract the natural tendency of gas jets to remain intact and resist sidewise expansion. It is possible, however, to make use of this natural tendency of jets, and inci-

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dentally secure a very high degree of incandescence, higher in fact than is possible by any other known means, using air and the same gas. Moving the nozzle away from the baffle and making the baffle porous, (using for convenience in experimental work a pile of refractory granules) the top or impact surface may be shaped to conform to the natural mushroom of the jet as it strikes. For any degree of porosity, and jet velocity or supply pressure, there is some best distance and impact face shape, that permit all mixture striking, whether at

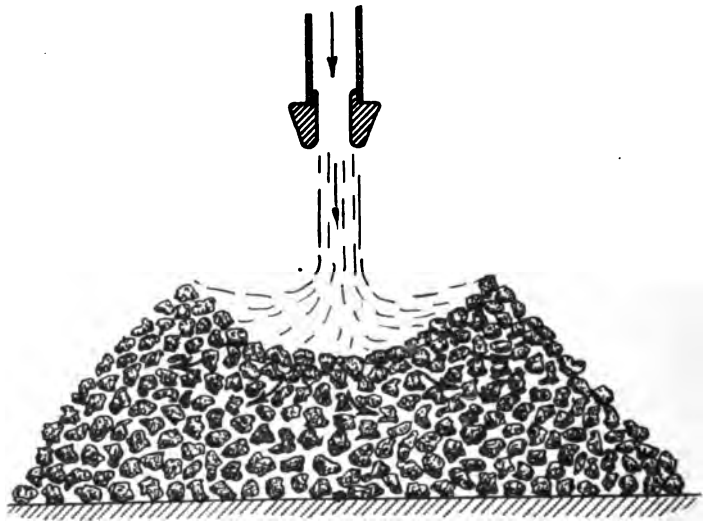

Fig. 5.—Means for localizing the combustion zone at the external radiating surface.

the center or edges, to have just the right velocity, that of propagation, in contact with the material, so that combustion takes place in contact with the outer or radiating surface which then has the maximum possible temperature. It is essential that the impact face be porous, so that the products may readily escape through instead of forming dead gas films which separate the combustion surface from the solid faces and insulate the latter from the heat of the former. In this

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manner a surprising degree of radiance is obtained, due to the high rate of combustion of a mixture containing no excess air except possibly at the outer edges by entrainment. At 3.2 inches mixture pressure 40 cubic feet of gas per hour were burned over about four square inches of surface, which corresponds to over 1,400 cubic feet per square foot per hour and more than 800,000 B. t. u.'s per hour per square foot. Higher rates of combustion than this are obtainable but not all developed on the radiating surface itself.

In view of the importance of developing as large an amount of heat as possible in the radiant form, in addition to the localization of the combustion zone, and considering that loose granules or porous diaphragms of refractory may serve the double purpose of the radiating screen and of the actual baffling or mixture stream spreader, everything else may be abandoned in favor of these refractories, except perhaps for certain special purposes for which special forms may be best. Nearly all the work done has been concentrated on an effort form bore, and if when cold the flow velocity is great enough to learn how these granular beds and bonded diaphragms should be handled to yield commercial apparatus, and by reason of the simplicity of the loose bed it has been consistently favored for most uses over the bonded. A uniformly grained bed of loose granular material will act as a substantially perfect spreader of the mixture issuing from an orifice covered by the bed but the quantitative effect of variations in size of grain, imperfections in shape or non-uniformity of size, together with shape of bed and its relation to shape, size and position of the feed orifice, are all to be determined by experiment only. Most of the detailed data of this sort will be omitted as not of general interest, but the following series of experimental determinations illustrate the most important of the general principles that must be observed for successful operation. One of the simplest imaginable arrangements is shown in Fig. 6 where a single nozzle 5/16 inch in diameter projects 1¼ inches into a bed of broken fire brick which

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material is very convenient for studying the ultimate position and shape of the combustion zone, as the material will fuse and bond at that place. The bed was held in a square brick box 6¾ inches on a side and 5 inches deep and the nozzle was fed with mixture at 3.2 inches pressure and starting with coarse grain ½ inch to ⅜ inch, the mixture on ignition flashed instantly down through the bed, locating below quite near the nozzle, as shown later by the more or less spherical lump that fused together. The same action took place with smaller grain

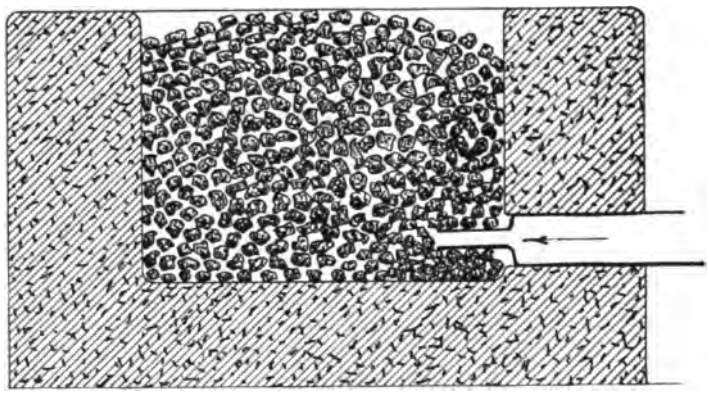

Fig. 6.—Apparatus for demonstrating the spherical form of the combustion surface when mixture is supplied from a nozzle surrounded by granular refractory.

as it was reduced in size successively from, 3/8 inch to 5/16 inch, 5/16 inch to 1/4 inch, 1/4 inch to 3/64 inch 3/64 inch to 5/32 inch, 5/32 inch to 3/32 inch, but a further reduction in size resulted in a different action. On using grains from 3/32 inch to 1/16 inch, in size, the mixture on ignition burned on top instead of flashing down through the voids to its normal surface about the nozzle. In a few minutes the top layer became hot and then seemed to cool but scraping away the top it could be seen that the combustion surface had receded and after running a sufficient time this progressive heating from the outside down toward the nozzle, resulted in a final loca-

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tion of the combustion zone about where it was before, with the coarser material with which it flashed back instantly to its normal position. Of course, in either case the whole bed gets hot in time but with coarse grains it heats from the normal combustion zone near the nozzle out and upward, while with small enough grain the outside top heats first, the flame drawing down slowly, a difference in action which requires an explanation.

When the grain is fine enough it acts like a flame interrupting screen, each little crevice between neighboring grains discharging so little mixture that its heat of combustion can for

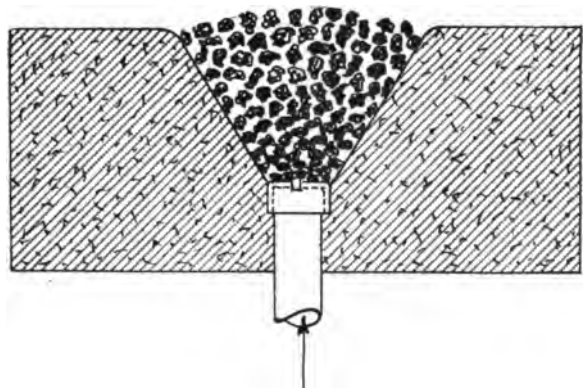

Fig. 7.—Apparatus for demonstrating uniformity of position of combustion surface with different sizes of grain.

an appreciable time be absorbed by the solid grain in contact without raising the lower side to the ignition point, radiation from the outside surface helping to keep down the temperature. In time, however, the lower side of the top layer gets hot and the combustion surface recedes, doing so more rapidly once it has passed under the top layer because then radiation cooling is lessened, leaving more heat for the grain to take up. It follows also that with the finer grain the less total mixture will escape from such a round nozzle as it tends to fill the orifice, so the total amount of heat developed will be less than

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with coarse grain. To show that the stoppage of the nozzle by the grain reducing the total gas flow and heat generation with fine grain is not responsible for the difference in flame action at the start as compared with coarse grain but that the difference is due to the difference in the mode of gas flow through the bed itself with corresponding more intimate contact between mixture and grain the smaller the latter. The same series of results were obtained in a pyrimidal chamber, shown in Fig. 7, in which the nozzle is a pair of hacksaw cuts in a 1 inch pipe cap, the whole being shown in the photo-

Fig. 8.—Apparatus for demonstrating uniformity of position of combustion surface with different sizes of grain.

graph, Fig. 8. With such slot outlets for the mixture the flow is substantially the same for all the different sizes of grain given, yet, not only did the top heat first with the 3/32 inch-1/16 inch grain and then burn back but also with the larger 5/32 inch-3/32 inch, with which it required ten minutes to draw the combustion zone down through the bed to its normal place and fuse a lump of granules over the cross slot.

In establishing the action just described, the use of fire brick as the grain was most satisfactory as each test gave a fixed

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record of what had happened in the form of a fused lump, but once it was clear that the size of grain made only a starting or temporary difference in action, then longer runs became desirable to bring out the possible heating effect on the nozzles and for these long runs refractory grain was used, including magnesite, chrome ore, both natural lumps and broken brick, fused silica, lime and alundum. With these materials the long runs showed that some forms of feed orifices became heated so as to ignite the mixture in the feed pipe while with others this action did not take place, permitting operation for an indefinite time. It was not clear at the time just what caused the trouble since it frequently happened that the nozzle that worked best was really much hotter than another that flashed back almost as soon as the steady state was established. At any time an increase in the pressure at which the mixture was supplied would have so increased the volume of flow as to drive the combustion surface to a safe distance from the nozzle but it was deemed unwise to leave the matter here, because first, all domestic apparatus must operate on low pressure, lower than that of the gas in the local mains, and second, all industrial apparatus, for which gas pressure boosting would not be objectionable, would at some time be operated at part capacity or turned down, which is equivalent to low pressure operation.

The next question investigated, therefore, was this permanence of the localization of the flame surface or combustion zone, and the discovery of means for securing an indefinite time of operation without disturbance from long continued heating even over several days even with low mixture pressures so low as to heat the hearth end of the nozzle above the ignition point. It is clear at the start that iron, or in fact any metal, must be kept away from the feed orifice proper which in effect means that in order that appliances may operate on low pressures it is necessary that the mixture enter the fire chamber through a refractory orifice or when the burner is lined with refractory, as it should be, the mixture must enter through a hole in the lining or what might be properly called

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the hearth. A long series of experiments were made with different mixture entrances that were for a time extremely puzzling but which finally could be summed up in a very few words. All feed holes will become incandescent at the fire end with low gas pressures and heat will flow back through the bounding material of the hole and these hot walls will heat the mixture passing through. No harm will result, however, even from a bright red heat on the walls of the hole, provided the latter is of uniform bore over the heated part and has no enlargement of cross section with corresponding low mixture flow velocity except at points that never get hotter than the point of ignition. To put it otherwise, the mixture passageway may be at any temperature without harm if of uniform bore, and if when cold the flow velocity is great enough to prevent back flash. Under these conditions localization of the combustion will be permanent. Naturally anything that will reduce the temperature of the supply tube, like radiation to the air, will also shorten the length of the necessary uniform bore portion as will also the use of more non-conducting material. Finally it was found that the length of uniform bore feed pipe that would be cool enough at its supply end to be joined to a larger mixture header or box, was greater for large than for small holes or that the allowable length was a definite number of diameters. For example, in an apparatus such as illustrated in Fig. 9, with a single refractory lined tube, feeding a cylindrical combustion chamber, all of alundum cement encased in metal, a hole of ¼ inch diameter and 6 inches long could be operated indefinitely at 1 inch water pressure even after the chamber had been made very hot by previous operation at much higher pressures, whereas a $^{7}/_{16}$ inch diameter hole of the same length flashed back at 1.5 inch water pressure, and continued to do so after periods ranging about three hours even after its length had been increased to 15 inches. Small diameter orifices of say $^{1}/_{16}$ inch diameter have on the other hand been operated indefinitely on pressures as low as 0.2 inches of water when about 1½

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inches long. Back flash after long periods of operation by heating up of the supply system may, therefore, be prevented by proper design, that is, by selection of suitable proportions in accordance with the announced principles and the established data and localization of the combustion zone will be correspondingly insured against disturbance.

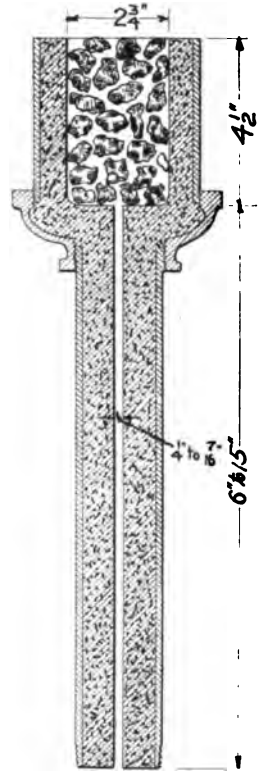

Fig. 9.—Apparatus for determining the ratio of length to diameter of feed hole to control "Back Heating."

Rate of Combustion per Square Foot of Bed or Hearth.—Passing now from the discussion of localization of the combustion zone or flame surface and the means for keeping it permanently localized, the next question of importance is that of

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control of rate of heat generation per sq. ft. of fire bed, which is a problem of distribution of the burning mixture over surfaces as large or small as may be demanded, and of maintaining high or low degrees of incandescence over these surfaces. This now seems a very simple matter but for a considerable time it seemed even more elusive than the prevention of back flash through nozzles, which was annoying enough. There are really two problems here and though related the relation is not as clear as it might seem. First, the problem of the high rate; at how high a rate may gas be burned and how may the structure be formed so as to permit of steady supply, and combustion at this rate over any given surface, and second, the problem of the low rate; can such mixtures be burned so slowly as to keep a surface just hot enough for frying for example, and may such a burner be turned down to a so-called simmering point without giving trouble, and if so, what ideas must be incorporated in the construction?

The problem of the high rate is the simpler of the two, as this may properly be termed the natural rate, assuming, of course, that suitable refractories are obtainable for the corresponding high temperatures and that the principles of permanent localization of the combustion zone are understood and incorporated in simple construction of apparatus. When the whole cross section of bed is taken up by the burning gas stream or when the combustion zone occupies the whole of the bed cross section, then mixture is being supplied as fast as it can be burned within the space available, and any increase in rate of supply will tend to push the combustion zone away or result in the phenomenon of blow off. This is the condition at the limiting high rate of combustion and is the natural rate because the advancing stream of mixture fills the whole available cross section of fire zone and combustion surface coincides with bed cross section in area. To establish this high rate it is necessary that the mixture be supplied at first when everything is cold, at a lower rate and after the bed is heated then its accelerating effect may be relied upon to hold localized a very much increased rate of mixture supply up to a certain maxi-

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mum, which is the natural or high rate of combustion. This natural high rate is intimately associated with the pressure of the mixture at the point of supply, or more properly, the drop in pressure through the feed holes or orifices, for holes of any given size. For example, in such a simple apparatus as that of Fig. 9, where a single feed hole supplies a combustion chamber of larger cross section, carrying a loose granular bed, it is evident that at some low pressure the combustion surface will just cap the feed hole and the rate of combustion will be natural for a bed area equal, not to the actual bed of 2¾ inches diameter, but on the contrary, equal to that of the feed hole, a fraction of an inch in diameter. Increase of mixture supply pressure will push the combustion surface away from the hole until finally it will extend across the whole bed and have a form approximating a section of a spherical surface lying within a cylinder, the axis of which passes through the center of the sphere, which latter will be located at the center of the feed hole. It is this latter condition that gives the high rate and to secure it the supply pressure must be big enough to send through a small feed hole, say ¼ inch in diameter, enough mixture to spread out and fill the voids in the bed 2¾ inches in diameter, which will exceed half the free cross section, while at the same time the flow velocity through the enlarged cross section must be as great as the rate of flame travel backward. If the ratio of bed area, with a given percentage of voids, to feed hole area is large then high mixture pressures must be used to secure the natural high rate, so if only small mixture pressures are available then the free flow area of the bed may not exceed the area of the feed hole by very much. In any case large beds may be heated by the high rate of combustion only by multiplication of orifices spaced at distances equal to the diameter of the combustion surface natural to the supply pressure in use. Before such spacing of feed holes for high natural rates of combustion can be found, it is first necessary to investigate the action for a single hole in a given bed, to find the relation between feed pressures and the ratio of active bed area to feed hole area that will cause the combustion surface to fill the whole

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bed between the enclosing walls. As an illustration of the method of procedure, it being impossible here to record much of this sort of data, the results of a single series on the apparatus shown in Fig. 9, will serve. In this series the pressures were never extended above 12 inches of water at the point of mixture supply and began with a single hole $^5/_{16}$ inch in diameter, discharging into a cylinder 2¾ inches in diameter, area 6 square inches, but as increase of pressure to the maximum noted, failed to supply as much mixture as could be consumed in the available area, there was added a second, a third and finally a fourth hole, even then not reaching the limit. With the four holes and at a pressure of 10½ inches of water, there was attained a rate of combustion of 2,460 cubic feet of gas per square foot of bed per hour, which on a calorific value of 600 B. t. u. per cubic foot is equivalent to 1,584,000 B. t. u. per hour per square foot. There was no indication that the limit had been reached, but as the rate was high enough for practical purposes, so high as to give trouble with available refractory materials, this series was not carried beyond these limits though it could easily have been done with higher pressures or with a larger feed area than four $^5/_{16}$ inch holes = 0.3 square inches. The conclusion here is, that rates higher than have been known are easily obtainable and rates higher than any refractory in common use can resist, so if any service arises that demands such rates, the demands can be met. It might be noted here that of several refractories tried the most satisfactory found was white alundum, with linings of alundum cement, preferably mixed with alundum grain of several sizes, properly proportioned dry to fill the voids, then mixed wet, rapidly dried and finally baked at a bright red heat. The size of grain in the loose bed and the depth of bed do each exert an important influence within limits, but in general for these high rates the larger the grain the better, though there is little if any advantage beyond one inch diameter, the depth in any case being little more than sufficient to prevent the gases lifting the grain off the hearth. The resistance in the bed is always less for round grain than for flat

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and appreciably so, and in this respect the form of fracture of white alundum is most satisfactory. In the above mentioned series white alundum from ½ inch to ¾ inch diameter was used and the depth averaged 2 inches. The results of this series are given in curve form, Fig. 10.

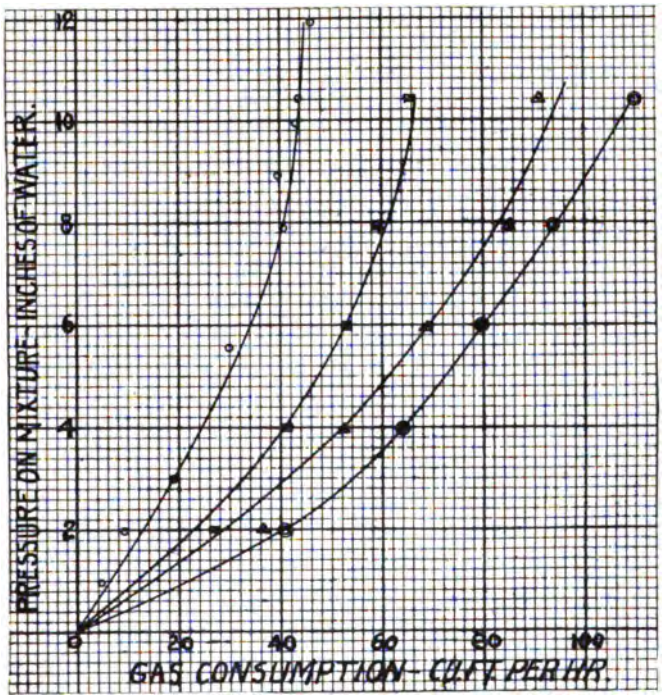

Fig. 10.—Rate of flow of mixture through different numbers of 5/16″ feed holes at various pressures.

Probably the most difficult of these experimental problems was that of finding a suitable structure for the permanent localization of the combustion surface for very low supply pressures, while at the same time securing any desirable low rate of combustion over the bed with a uniform incandescence at the surface such as would be suitable for cooking, for example. It is clear that the lower the pressures the closer to the feed

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hole will the combustion surface locate, the smaller the area of bed heated, and the stronger the tendency to back flash. This fact led to early attempts to secure low rate heat distribution by other means than that of feed hole supply with a series of spots, each having natural high rates of combustion, located practically at the mouth of the holes. Mixture supplied to a passageway filled with fine granules or a porous brick, will flow much the same as through a pipe as the porosity supplies a multiplicity of small paths more or less mutually communicating, and a given quantity flowing would have a mean velocity through such a porous layer, the same as through a pipe of cross section equal to the voids except for differences in friction. Mixture fed into such a bed in any convenient way, ranging from a single hole under a thick bed to a great number of holes under the whole bed, obtainable by a metallic screen support for loose granules, or the under surface itself of a bonded diaphragm, would discharge the mixture uniformly from the top of the bed, however the supply was arranged, if the bed were thick enough. This seemed to be at first the most promising idea to follow for low rate heat distribution especially as changes of area of flow path so necessary for localization can be obtained by two means quite conveniently; first, by using two layers with the upper coarser and, therefore, with more free voids than the lower fine bed, and second, by changing the diameter of the containing walls that hold the porous bed.

At first only loose granules were used in apparatus such as shown in Fig. 11, where a perforated metal plate of 306 holes per square inch, diameter 0.033 inch, and 27.8 per cent., free opening, is supplied by a ¾ inch pipe, discharging into a conical space under the screen. On the top of the screen rests a one inch bed of granules 8/64 inch to 6/64 inch, and over it another one inch layer of larger grain, 24/64 inch to 20/64 inch diameter. On lighting the mixture supplied at 2 inches water pressure the combustion zone instantly locates between the layers at the point of change of free flow space,

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due to the difference in voids, but as the heat penetrates the lower or fine bed, the combustion zone works back to the screen, which happens with these conditions in about ten minutes. All sorts of changes in the relative sizes of the material and thickness of the two beds or number of layers yield no difference in the result except as to the time it takes the combustion zone ultimately working back to the screen, burning it out, or causing a flash back, or both. This is clearly due to insufficient velocity of flow at the supply end of the bed

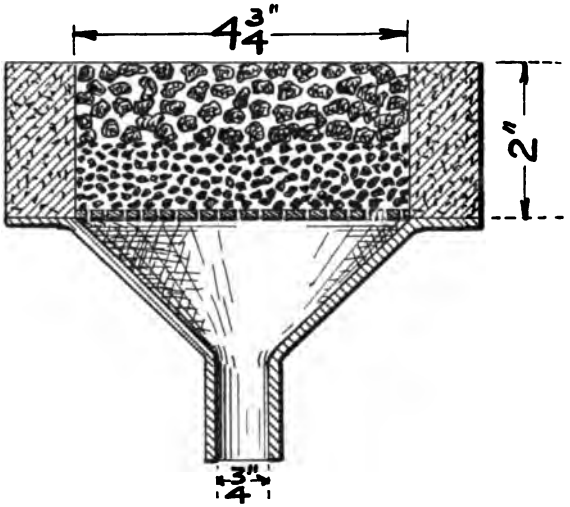

Fig. 11.—Means of controlling surface distribution of heat by mixture supply to fine granular bed on screen.

and suggests a contraction of the walls toward the lower end, as in Fig. 12, where a slot supply is substituted for the screen as it does not burn out so readily if by accident the flame should work down that far. As before, however, the combustion zone worked down close to the nozzle but not so quickly as before, suggesting a further narrowing at the bottom to form a neck as in the forms successively tried, as shown in Fig. 13, 14 and 15. As the neck is thus narrowed the combustion surface no longer approaches the nozzle so closely,

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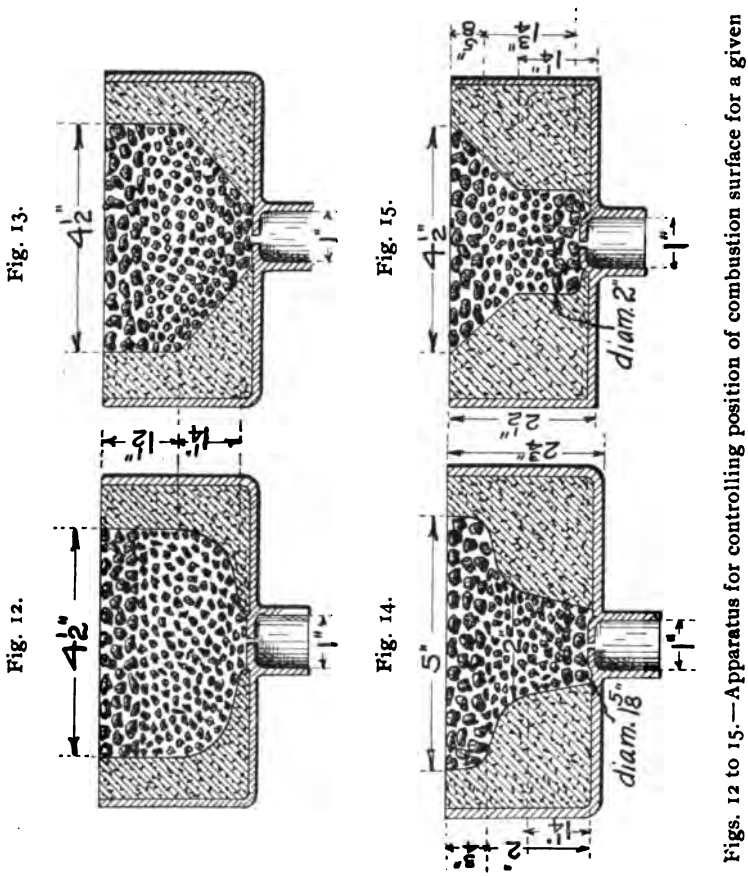
stopping, in Fig. 13, for example, about 1 inch above after ¾ hour at 3½ inches pressure, and in Fig. 14 stopping about 1½ inches above, while in Fig. 15 it did not enter the lower cylindrical portion at all.



Figs. 12 to 15.—Apparatus for controlling position of combustion surface for a given heat distribution over the radiating surface.

By adjusting the space between the walls, the flow velocity through the lower or fine bed can, therefore, be kept high enough to control the location of the combustion zone, regardless of the manner of feeding the mixture to its narrow bot-

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tom part, but the problem is by no means solved. All these latter forms are bad in another respect because with the thickness of bed above the combustion zone the top is hot in the center and cool at the edges. To get an even top heat, a greater thickness of bed above the combustion zone would be required but this is already too thick to give a quick initial heating, so another change in construction is suggested, incorporating a different relative position of the narrow lower neck of fine material and the top surface maintaining about the same relative areas as in the last case, which were found sufficient to hold the combustion zone above the cylindrical portion. Such an alteration was made by enlarging the cylindrical portion and inserting a solid core 3½ inches in diameter so the mixture rose in a thin ring ¼ inch thick around the core, filled with fine material and then spread out at the top, heating a bed of 5 inches diameter. This gave a better top heat distribution but took too long to reach a steady state,—almost an hour. After many trials of various proportions it became clear that if uniform top temperatures are to be quickly obtained with low rates of gas consumption over extended surface that single feeds through single or double porous beds will not suffice and some other plan must be employed.

The failure of the single point supply to distribute mixture so as to not flash back and yet quickly and uniformly heat the top of a radiating bed with a low rate of combustion, leads to the conclusion that multiple feed orifices must be used and so spaced as to give the heat distribution desired at the available pressure, a surface bed or radiating screen of sufficient thickness, serving to localize the combustion and to equalize the otherwise spotty appearance. It might appear that this could be done by drilling holes in a plate dividing the combustion chamber from the mixture supply chamber, but from what has been said about the conditions for permanent localization of the combustion zone, it is clear that such an orifice plate will sooner or later heat through, becoming hot enough on the supply side to ignite the mixture there

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before its entrance into the feed holes. Any sort of feed hole plate is out of the question unless provided with means for removing heat received on the combustion chamber face, fast enough to balance heat conduction through it toward the source of supply, and effective enough to prevent that side from becoming a point of ignition.

It has been shown that a single long feed hole supplying a combustion zone can be proportioned so as to permanently resist backward heat flow well enough to insure indefinite periods of operation, so it naturally follows that several feed

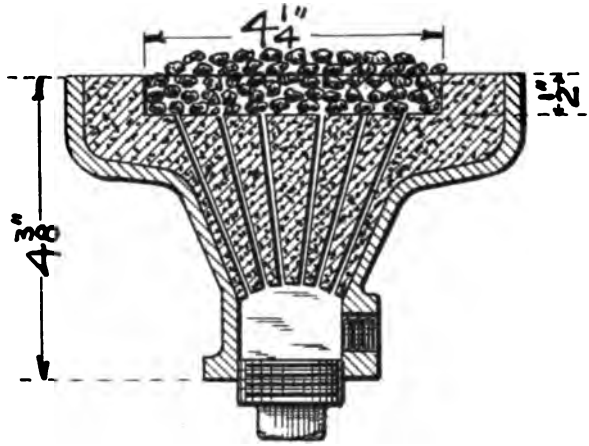

Fig. 16.—First cook stove top burner in which localization of combustion surface, back heating, distribution of heat over radiating surface are all controlled.

holes might be grouped so as to be fed from a common point, discharging mixture at the other end over as large an area as needed for any desired surface rate of combustion, and so proportioned as to resist heat flow as effectively as with one, if the necessity for the latter is kept clearly in mind. This conception is the basis of the construction shown in Fig. 16 which has 30 holes molded in alundum cement by wires held in hole plates at the ends and radiating from a 1½ inch bottom chamber in the iron container casting, to a 4¼ inch diameter cir-

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cular top bed. To insure the supply chamber end of these feed holes against a rise of temperature to the ignition point, it is necessary only that the distance between this point and the hearth be long enough. When it is, the dissipation of heat from the side walls will be large enough to balance the heat carried down through the solid material surrounding the holes, and the dimensions shown in the sketch have proved to be adequate for this purpose. Two photographic views of this burner are shown in Figs. 17 and 18, the first reasonably practical burner for stove service operating on surface combustion principles but still imperfect in some respects. To uniformly

Fig. 17.—First successful cook stove top burner, solid type, top view.

heat the top bed of loose grain of white alundum or broken fused silica, ½ inch thick, 34 holes were molded, as shown, by wires 1/16 inch diameter and spaced in three rings. This arrangement gave a quite uniform top heat and was operative at low gas and mixture pressures for an indefinite time, for, although the holes of the central group were often red hot for over 1 inch below the hearth, the heat dissipation from the sides was always sufficient to prevent the lower end of the holes ever reaching the ignition temperature. The propor-

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tions used were selected to give consumptions somewhere near those of the standard top burners of ordinary gas cook stoves, that is, at mixture pressures of 2½ inches water the consumption was intended to be about 15 cubic feet of gas per hour, which is equivalent to about 100 cubic feet of mixture. Naturally, variations in bed thickness, size of grain or even kind of grain, will cause changes of resistance, the latter due to the variations in the voids, corresponding to different characteristic fractures, silica, for example, tending to form flat faces while white alundum breaks more nearly round. The characteristic consumption tests at various low pressures are given

Fig. 18.—First successful cook stove top burner, solid type, side view.

in curve form, Fig. 19, showing that at 2.5 inches water this stove burner consumed about 17 and 15½ cubic feet of gas with the silica and white alundum beds respectively, the standard of 15 cubic feet per hour being equivalent to 150 cubic feet per hour per square foot. By varying the diameter, length and spacing of holes, keeping the general arrangement here indicated, practically any desired rate is obtainable, though the general design is the result of the search for a construction suitable for a properly distributed low rate of combustion.

To illustrate the ease of adaptability of this general type

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construction of surface combustion burner to any desired rate over any surface, three other burners are shown, one each designed for a muffle furnace, a crucible furnace and a steam

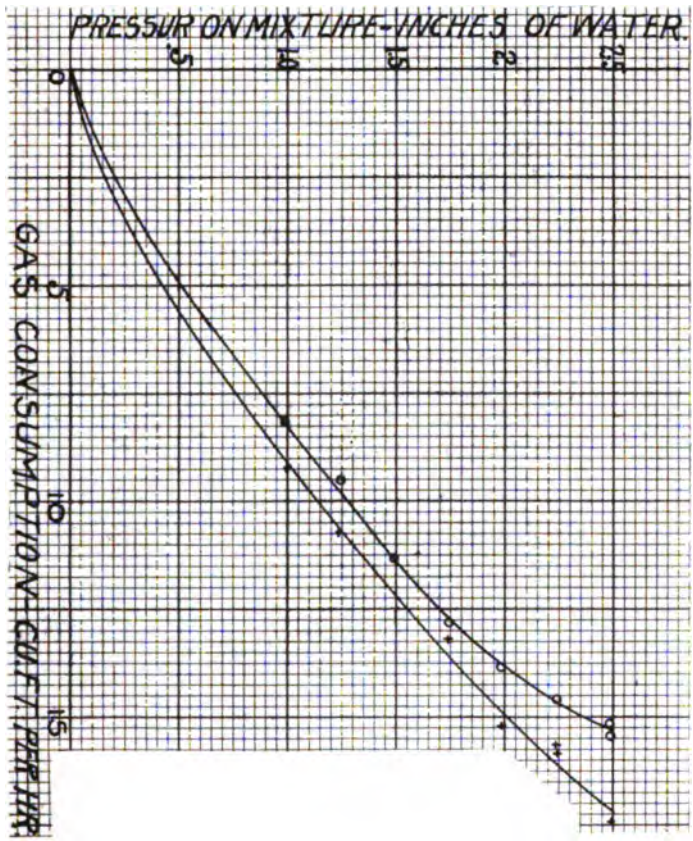

Fig. 19.—Rate of combustion at various pressures on circular bed, $4^1/_4''$ in diameter, supplied by 34 holes, each $^1/_{16}''$ diameter. Upper curve for a bed of white alundum, $^{20}/_{64}''$ to $^{24}/_{64}''$ grain, $^1/_2''$ thick. Lower curve for a bed of fused silica $^{20}/_{54}''$, to $^{24}/_{64}''$, $^1/_2''$ thick.

boiler fire, respectively. The first of these, intended for placing below an assay muffle, is shown in sketch form in Fig. 20 and photographically in Figs. 21 and 22, on which latter the

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chalk line indicates the beginning of the feed holes. This burner had a rectangular hearth, 6 inches by 10 inches, supplied by 96 holes, molded in alundum cement in a cast iron

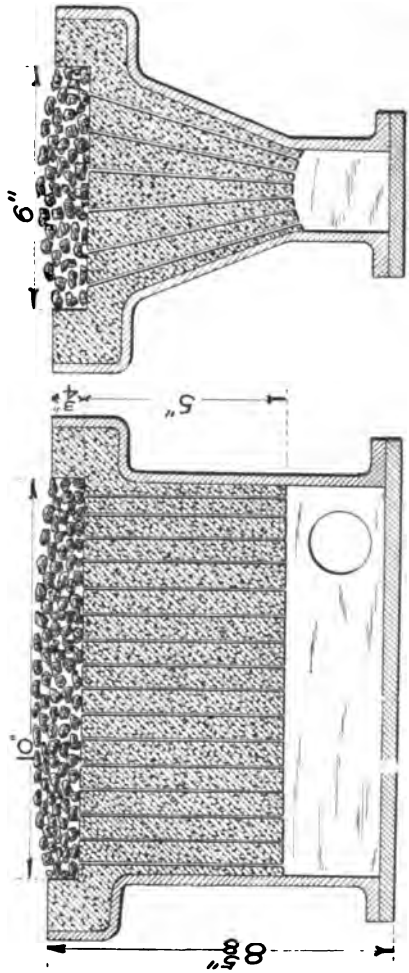

Fig. 20. — First form of muffle furnace burner, solid type.

casing and at 3 inches of water mixture pressure consumed 120 cubic feet of gas per hour, over 60 square inches, equivalent to 288 cubic feet per hour per square foot. A still higher

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rate over an annular hearth was obtained in the small crucible furnace burner of the same general type shown in Fig. 23, the combustion zone lying between the side insulation and a central cylindrical muffle used to keep the crucible chamber clear but not at all essential to the operation, though it helps to keep the crucible bottom cooler than it otherwise would be. In this burner 20 holes, each 0.14 inch in diameter, were distributed so as to be on the surface of a cone supplying a hearth lying between two circles, 4½ inches and 2¾ inches in diameter, the area of which is, therefore, 15.9 — 5.9 = 10 square inches. The consumption was 40 and 47 cubic feet per hour at 2.5 inches and 3.0 inches respectively, which are equivalent to 576

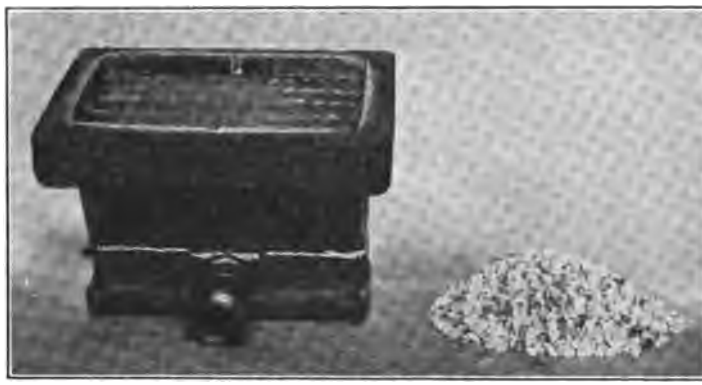

Fig. 21.—Top view of solid type of muffle furnace burner, showing white alundum loose granular bed at side.

and 677 cubic feet per hour per square foot of hearth. An example of how this type construction may be adapted to extension of hot surface or hearth over large areas without excessive length of holes in the solid group is shown in the photograph, Fig. 24, where three sections of wedge form, each 1 by 3 feet, make together a hearth of 9 square feet. This burner was tried out in the fire box of the Baldwin locomotive in the Mechanical Engineering Laboratory at Columbia University as to its capacity and the proper design of fan blast

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and pipe connection. Mixture was supplied through a 12 inch header to three 5 inch branches, one to each burner and gas supplied through a 6 inch main from the street was measured in a Wylie proportional meter, loaned for the purpose by the Equitable Meter Co., and at 10 inches water the rate would be 20,000 cubic feet of gas per hour.

While the molding of groups of feed holes in tapered banks, long enough to keep the mixture chamber from reaching the

Fig. 22.—Side view of solid type muffle furnace burner, showing bed in place.

ignition temperature, is a perfectly feasible mechanical construction and capable of insuring indefinitely long operation at any desired rate of combustion per square foot of hearth, it has certain disadvantages that warrant a search for an improvement that will remove them. In the first place it is somewhat troublesome to mold the plastic material between casing and wires so as to secure a solid mass that will not crack on sub-

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sequent unequal heating, and when large these sections are very heavy and easily broken by shocks that may come when setting them in place. They are, moreover, necessarily high, too high for many locations, such as a cook stove or boiler furnace if present proportions of frames and settings are to be maintained. These with some others of minor value are sufficient objections to warrant a search for a better form

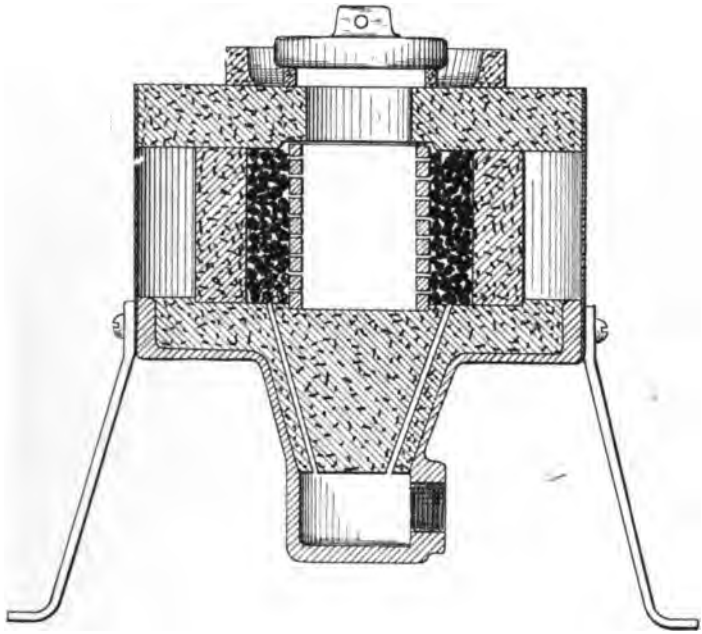

Fig. 23.—Construction of small, solid type muffle furnace.

though not enough to abandon the present form if no better is available.

Fortunately, a better form and one that is completely satisfactory in all respects has been found, and it naturally follows from a little analytical reasoning. The holes through which the mixture is to be supplied must be cooled, and the cooling must be effective enough to keep the supply end above the temperature of ignition, but no more cooling than will do this is necessary or of value. In addition, the holes must be spaced

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at the hearth for proper distribution of heat and the desired rate of combustion per square foot of hearth. Banking them in groups, as has been shown, will accomplish this, but it is clear that complete or partial structural independence of the holes by forming them in tubes so each may be cooled independent of the other or even forming them in ribs with independent cooling in at least two directions, is better and more effective than a form in which the heat to be dissipated from

Fig. 24.—View of three large solid type burners, forming an active bed, 3 feet square, capable of burning 20,000 cu. ft. of gas per hour.

an inner hole must be conducted past an outer one also developing heat of its own.

Accordingly this principle has been incorporated, and burners constructed that seem in every way to be satisfactory commercial forms for the essential element of all sorts of surface combustion apparatus. The construction of the first

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of these designed as a top burner for a domestic cook stove is shown in the sketch, Fig. 25 and photographically in Figs. 26 and 27, the casting and fire brick lining separate, Fig. 28, the

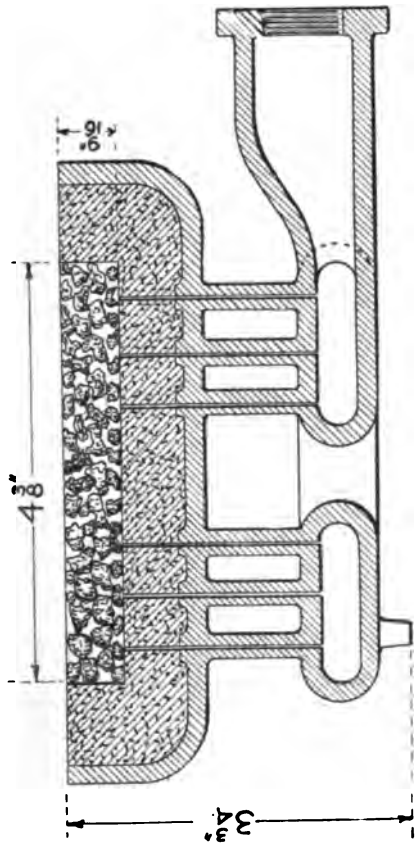

Fig. 25.—Second typical form of construction of cook stove burner (top). Heat distribution controlled by spacing feed holes. Rate of combustion by number and size of holes. Localization by velocity reduction at outlet from holes and back heating by separate cooling of the walls of each hole.

lining secured in place after drilling the feed holes in each of the separately formed cast posts. To insert the lining, wires are inserted in the drilled holes while pressing the lining in place, the cement forming a perfect hole in the hearth, exactly registering with the drilled hole in the casting. Fig 29 shows

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the completed burner with the granular bed in place, in this case crushed and sized fused silica. This burner has 35 holes each 1/16 inch in diameter but other diameters have been used, as well as other material for the bed of all sorts of thicknesses and while the consumption and top temperature vary with

Fig. 26.—Top view of second form of cook stove burner, showing casting before drilling, on the left, and fire brick lining on the right.

Fig. 27.—Side view of second form of cook stove burner, showing casting on the left, and fire brick lining on the right.

each, practically everything works well and any result desired by the designer is obtainable by simple selection of suitable dimensions. In Fig. 30 are shown a pair of characteristic consumption curves. Burners of this class have been thoroughly tested under both laboratory and kitchen service conditions, separately and as incorporated in complete cook-

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stoves, having in addition inverted broiler burners with 60 holes, 1/16 inch diameter in two rows, with a long narrow

Fig. 28.—Top view of second form of cook stove burner, showing fire brick lining in place and loose refractory filling at the right.

Fig. 29.—Second form of cook stove burner complete and ready for operation.

rectangular hearth having loose granular material held in place by wire mesh screens. Three of these placed in the top of the

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Vulcan hotel broiler shell gave consumptions of 38, 43 and 50 cubic feet of gas per hour at pressures of 1 inch, 1½ inch and 2 inch respectively, all making a bright broiling heat, that gives excellent service.

This screen construction is well shown by the illustrations of a curved face room-heater burner, designed to fit in a Vulcan heater shell in the photographs, Figs. 31, 32, and 33. The first shows the new heater complete with an automatic

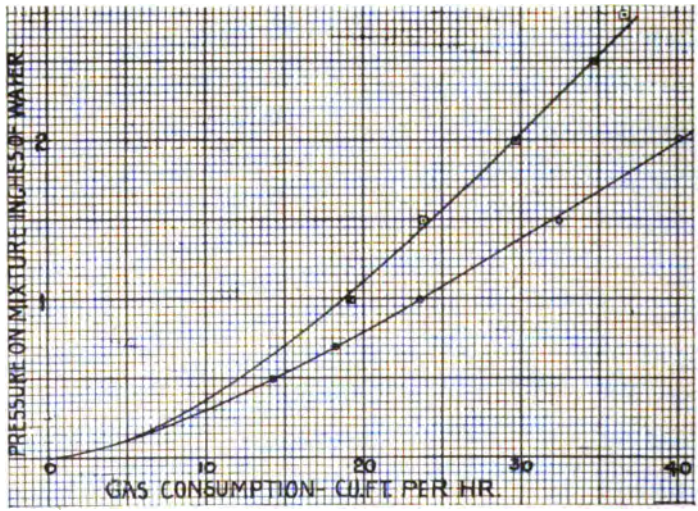

Fig. 30.—Rate of combustion at various pressures on circular hearth of cook stove top burner, $4^{3}/_{8}''$ in diameter with 33 holes, each $^{7}/_{64}''$ diameter, for lower curve, $^{3}/_{32}''$ for upper curve.

proportioning mixing valve, to be described later, while the latter two show the burner without its bed, as set on the base, and a separate side view. This burner has a rate of 14, 16½ and 17½ cubic feet per hour at 1 inch, 1¼ inch and 1½ inch pressure respectively, on a hearth 8½x5 inch = 42½ square inches supplied with 72 holes, 1/16 inch diameter, and in operation gives as strong a radiation of heat as is consistent with non-blistering of varnish on chair legs or ignition of carpet. While the refractory material is brightly hot, the No.

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18 B. and S., (four per inch) wire of the screen does not seem to be above a faint dull red and at this temperature all the alloys used in electric heater elements intended for operation at bright red heats up to 2,000° F without serious oxidation, will give good service in this location as will also common cast

Fig. 31.—Radiant room heater equipped with second form of tubular type burner, set in original shell of standard Vulcan heater. Loose bed held in place by wire mesh Nichrome screen.

iron grids. Burners of any shape or size suitable for all sorts of household and hotel cooking and heating service can be produced along these lines to work in any position, by the ordi-

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nary processes of design, involving no more complex mental processes than are required to select suitable materials and

Fig. 32.—Radiant room heater burner on base without bed or shell.

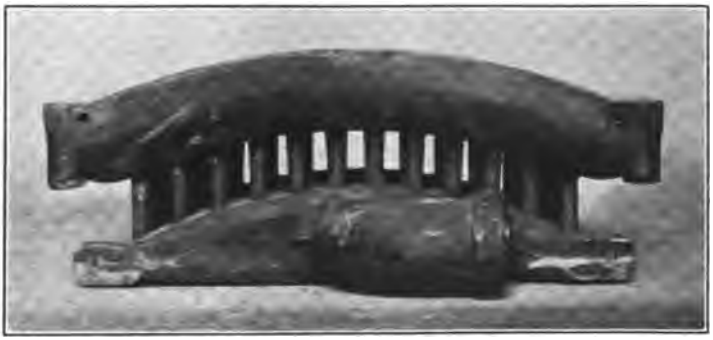

Fig. 33.—Side view of tubular burner of radiant room heater.

dimensions with the aid of established data or obtainable by simple experiment in any laboratory.

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This same principle of supplying mixture through more or

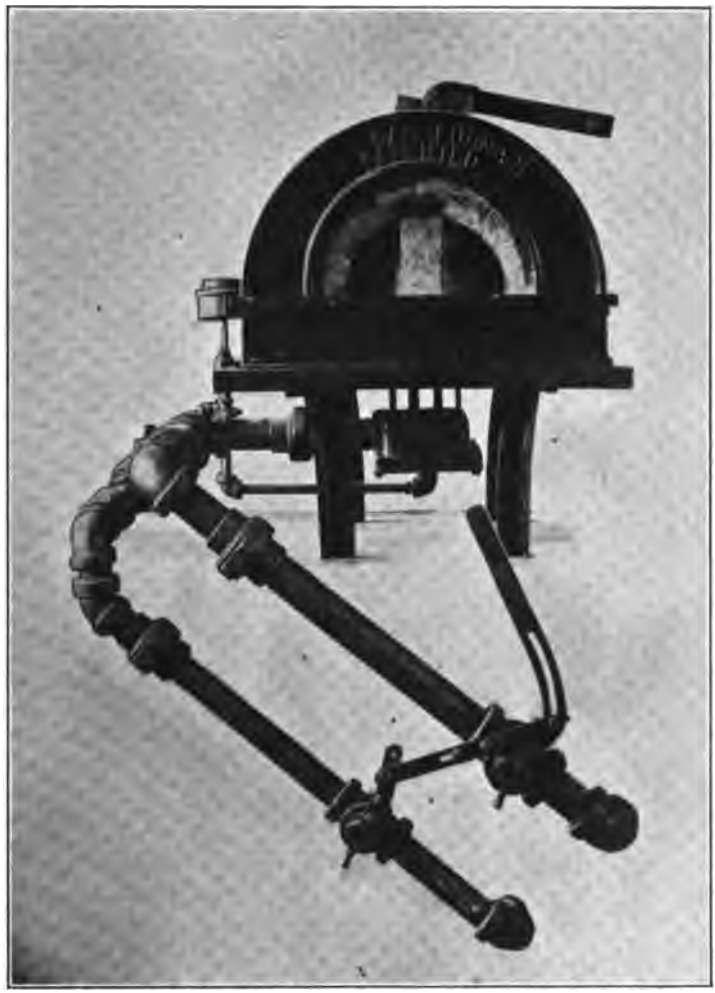

Fig. 34.—Front view of muffle furnace, showing ribs, carrying the mixture feed holes.

less independently cooled feed holes formed in metal walls and discharging into registering holes in refractory hearths,

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has been applied to higher rate appliances than those of domestic service, such as the muffle and crucible service, and one each of these is shown by the photographs, Figs. 34 to 37, both with feed holes drilled in ribs, which allows the same

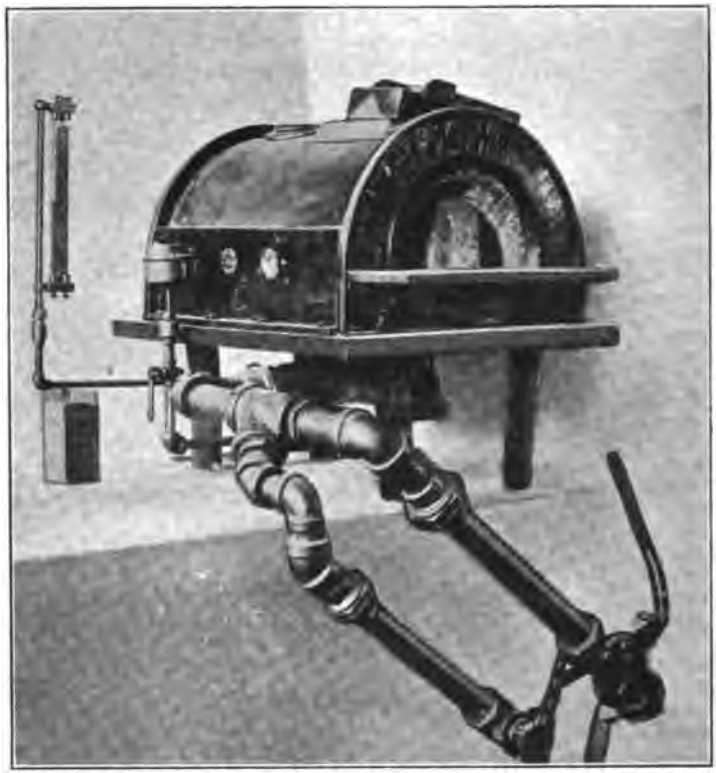

Fig. 35.—Side view of muffle furnace, showing small mixture sampling burner at the left with shut-off cock.

casting to be used for a wide range of capacities by changing drill sizes and center distances. The assay muffle is shown in Figs, 34 and 35, the former being a front view, showing the two ribs carrying the feed holes with a few separate tubes placed at the side and front to develope enough extra heat

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to counteract the open front end muffle cooling, and equalize the temperature throughout the muffle. At the left hand side is shown a single orifice sampling burner with open bed, consuming 2 feet of gas per hour and used to adjust the mixture proportions, slight changes in which are readily recognizable by the appearance of this small open fire. The main

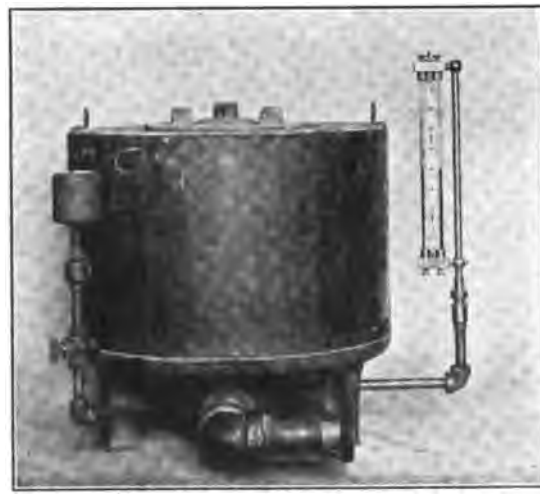

Fig. 36.—Side view of crucible furnace supplied by holes drilled in radial ribs between mixture chamber and furnace box. Mixture sampling burner is shown at the left.

burner is operated normally at 116 cubic feet per hour and always gives a very good thermal gradient, as shown by the following figures, with the above arrangement. The really

THERMAL GRADIENT IN MUFFLE WITH FLUE AT TOP FRONT.

Distance from front of muffle	Door closed, no draft, temp. °F.	Door open, good draft, temp. °F.
2 inches	1,760	1,600
4 "	1,870	1,742
6 "	1,900	1,820
8 "	1,910	1,852
10 "	1,900	1,840
Back 12 "	1,900	1,820

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significant thing here, however, is the ease with which any gradient desired can be obtained by changing the quantity of mixture supplied at different points, entirely independent of flue location. The crucible furnace shown in Figs. 36 and 37 is fed with two rows of holes drilled in a series of radial ribs and discharging in the annular space between insulation and muffle as can be seen in the first illustration with the top removed and which view also shows a sampling burner. The second shows the side appearance and bottom mixture chamber

Fig. 37.—Top view of crucible furnace with cover removed.

from which the feed ribs run upward to the base, all cast in one piece. The mixture holes discharge into a hearth of alundum cement on which rests the cylindrical alundum muffle and after one run at about 10 inches water pressure, both muffle and hearth softened as shown by Figs. 38 and 39, on which the permanent shrinkage cracks clearly show as do also some pieces of white alundum that adhered to both muffle and hearth. By a change of alundum bonding mixture, both of these parts may be made more refractory, sufficiently so for

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a considerable quantity of very high temperature work. It is not difficult, however, to consume in such a furnace enough gas to produce temperatures that will soften any available refractory, but by simply changing mixture pressures it is easy to maintain practically any temperature desired. If for any special purpose it should be necessary to maintain a secondary hot zone at any particular point, then separate mixture supplies can be led to that point and burned without

Fig. 38.—Top view of crucible furnace and hearth, showing the destructive effect of the high temperature on the alundum mixture.

interference with the products of combustion passing from another combustion zone, a condition peculiar to surface combustion, to which the well known "smothering" of common bunsen flames, is unknown.

Control and Adjustment of Radiating Surface.—By the application of the principles of construction so far developed, it is possible to make a surface combustion burner for any desired rate of combustion per square foot of hearth that will

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operate for indefinite periods of time without disturbance or adjustment, but for commercial apparatus even more than this is needed. One additional property that must be present is a suitable range of control of the rate, as few, if any burners are operated in practice at a constant rate of combustion whether used for domestic or industrial purposes. It must be possible, therefore, to adjust the consumption of any burner from a minimum low to a maximum high rate and to operate

Fig. 39.—Side view of crucible furnace muffle and hearth, showing the softening of the muffle by heat. Material of both, alundum mixture.

safely and surely at any one, no matter what the previous adjustment or the time of operation. Furthermore, some classes of service require a very prompt change in the radiating bed temperature after adjustment, which includes a very quick initial heating after lighting cold, while other classes of service require a slow change after adjustment or a sluggish

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response to changes. With any given range of adjustment of rates for safe working, there may be associated the requirement of a prompt or a sluggish response after a change, but fortunately in no one burner is it ever necessary or even desirable to provide for more than a limited range of adjustment, associated with either prompt heating or sluggish, never both. These conditions can be met in the sort of burners described sufficiently well to meet practically all service requirements consistent with maintaining the advantages of surface combustion as a process.

The range of control of rate of combustion depends primarily on the size of the feed holes and on the effectiveness of their cooling, and it is easily possible to make holes small enough in separate tubes or ribs to absolutely prevent back flash even when the mixture is turned off and the velocity of flow reduced to zero. By imposing sufficient mixture pressure on enough of these holes per square inch of hearth any maximum rate of combustion may easily be associated with this minimum rate of zero. Certain practical considerations such as the extra cost of forming small over large feed holes and the increased possibilities of stoppages in them make it desirable to use larger holes than correspond to a minimum rate of zero when that is not necessary, and it has been found that holes $^1/_{16}$ inch in diameter are small enough for safe operation at rates as low as most services require. Holes of this size in cook stove top burners, broilers and room heaters, can be safely operated at 0.2 or 0.3 inch pressure, giving thereby at least as great a range of adjustment as is possible with bunsen burners of the ordinary form without back flash. Such holes seem to keep free of stoppages and are cheap to form, if not much over 1 inch in length. Apparatus intended normally for much higher rates than the domestic class would naturally be given larger holes and, therefore, have a higher minimum operating pressure, but the range desired even with this higher minimum is easily obtained by using a correspondingly higher maximum. Thus while the maximum pressure available for operating domestic apparatus without gas boosting, which is

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out of the question here, is a little less than that of the street main, say 3 inches of water, that for an industrial furnace for which gas boosting is not objectionable may be made even with small fans as high as 12 inches and with positive blowers several pounds. Assuming the holes in the latter case to be such that the minimum safe pressure is 1 inch, there is a pressure range of 12 : 1 for adjustment of rate. Correspondingly, if the domestic apparatus has a minimum safe pressure of 0.2 inch, then it has an adjusting pressure range of 15 : 1. It must not be understood that these are limiting figures for they are not, being offered merely as examples, the real range may be made whatever is desired, a thing thought to be impossible in the early days of surface combustion development.

The time of heating is likewise within control though not through so wide a range, that is, by adopting suitable constructions the burner may be made to heat up from the initial cold to the normal working state in a short or long time, and will be correspondingly quick or sluggish in response to pressure or rate adjustments while in operation. Sluggishness is obtained by using a thick bed of great mass and, therefore, large heat storage capacity, while sensitiveness follows the use of beds or radiating surfaces as light as possible. It is clear that, taking for example the cook stove top burner, a bed only ¼ inch thick will heat quicker and respond more positively to valve adjustments than a bed 1 inch thick, other things being equal, and the time of heating the latter would approximate four times that of the former if there were no interfering influences. These influences are, however, present and are somewhat difficult to understand at first, but clear enough after study. In the first place, a reduction in the thickness of bed may leave it so thin that it is no longer effective in reducing mixture velocity at the hearth orifices, so that mixture will blow off at various points where the grain does not properly baffle a jet. The escape of this mixture actually reduces the heat developed in the bed, delays its heating, and so counteracts the expected gain from bed mass reduction, at the same time it causes a smell from the escape of the unburned gas,

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which of course ceases once the bed is heated even when the baffling is very poor. This is one of the difficulties encountered in the effort to reduce the initial heating time by reduction of bed thickness. It would seem that, if starting with grain ¼ inch in diameter, a reduction of bed thickness was carried so far as to cause partial blow-off by insufficient baffling, this could be corrected by a reduction of size of grain and this is so, but here again limits are met. In no case may the grain be so small as to fall into the end of the tube, but with the small holes used, even before this occurs, two other things are noted. A thin layer of fine grain on the flat hearth will not heat uniformly with the hole spacing satisfactory for larger grain, a series of bright spots above each hole with dark area separating will replace the uniform color of a thicker and, therefore, more sluggish bed. Again, the fine grain bed will not heat initially in the same way that the coarse one will, for below a certain grain size the combustion locates initially on the outside surface, which heats first, the combustion zone gradually working back toward the orifices, while with a larger grain, offering fewer and wider mixture passages in the voids, the combustion zone locates instantly about the holes, flashing directly through the bed. In other words, the fine grain bed heats from the surface inward while the coarse from the inside outward, and though for two such beds of equal weights of material it would seem that equal times must elapse before each had reached a steady state, as a matter of fact the one that heats first from the outside will be quicker because of the non-escape of unburned mixture while heating.

This reasoning leads naturally to one of the successful forms of quick heating top burners which becomes incandescent and uniform at the normal rate of combustion in about half a minute, the ordinary half inch thickness of large grain bed requiring three to four minutes, depending on the material. This one is formed by counter-sinking the outlet side of the 1/16 inch feed holes to ½ inch, filling the taper holes with silica of size 10/64 inch to 8/64 inch, and also covering the hearth to a depth of ¼ inch, as indicated in the sketch, Fig. 40.

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Reduction of mass to be heated without interference with the effectiveness of the baffles and by using materials that are permanent, is a definite problem for which there are many solutions, and no doubt others will appear as long as specific attention is given to it, but it is a serious question whether reduction of time below one minute or even to this time, is really advisable. There is available one type group of constructions already explained under localization, and that is the formed baffle of which the flat plate mushroom plug and ball in taper hole are examples, over which may be placed the radiant screen of metal, perforated or woven, a thin layer of loose grain, or a diaphragm of refractory perforated or otherwise

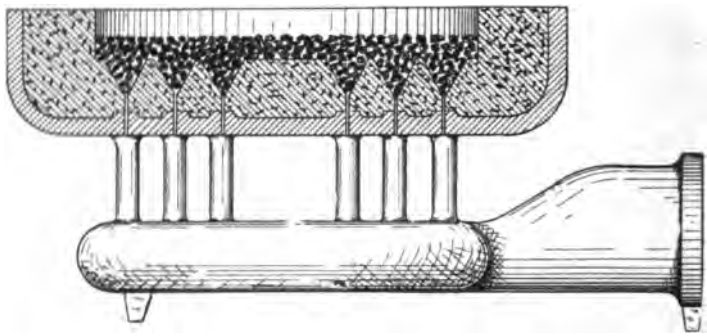

Fig. 40.—Modification of tubular type cook stove top burner for quick initial heating.

formed, to be porous enough to allow the free passage of gases, and all these have been used as well as some others that proved unsatisfactory. In the latter class fall a layer of picked asbestos fiber which heats as quickly as an illuminating mantle, but which has no life, a ¼ inch layer of hollow cylinders or short thin silica tubes like straight beads, ⅛ inch to ¼ inch diameter and ⅜ inch long, which heats in less than one minute and is permanent but too expensive, and a thin plate of alundum cement perforated freely with ⅛ inch holes, which becomes incandescent in one minute but is too fragile. In the former class fall the perforated metal non-oxidizing alloy

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plate over some form of direct baffle, and the molded porous diaphragm directly over the holes serving as both baffle and radiator, the former giving a very quick heating but not so permanent as the latter which, however, heats more slowly. For the metal plate two materials have been used, Nichrome II and Excello, the analysis of which are given below, as determined by Whitaker and Metzgar.

ANALYSIS OF NON-OXIDIZING ALLOYS.

	Nichrome		Excello
	Sample No. 1 Per cent.	Sample No. 2 Per cent.	Per cent.
Nickel.....	56.4	59.9	83.43
Chromium...	10.6	10.8	14.72
Iron	30.6	26.2	1.30
Manganese ..	2.1	2.3	
Silica.....			Trace
	99.7	99.2	99.45

The former has been most used and as applied to the problem of quick heating was in sheet form, 0.032 inch thick, perforated with holes 0.073 inch diameter and about one diameter apart. This was cut circular to fit the top burner hearth 4 3/8 inch diameter and heats to normal in about half a minute when set over baffles of the mushroom or plate type, and in about ten seconds with ball baffles. Such plates have a fair life if not operated at too high a temperature, about one cubic foot of gas per hour for each two square inches of radiation is a satisfactory rate and gives a good red heat. This construction may, therefore, be adapted as a direct competitor of the electric heater, using the same radiant material at the same temperature, but with gas as the source of heat instead of electric current. A series of consumption curves of one of these quick heating Nichrome radiating plates, 4 3/8 inch diameter, set over 35 holes, 1/16 inch in diameter, in the cook stove top burner hearth with mushroom baffle plugs is given in Fig. 41.

It is a serious question whether the reduction of heating time should be carried too far even in domestic apparatus in spite of a demand on the part of users for it because of the

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corresponding small heat storage. The top burner carrying a half inch loose bed has so much heat storage that it will resist interference from the spilling on it of large quantities of water or grease, amounts of which sufficient to be serious with bunsen burners have no effect here whatever, but the more this heat storage is reduced by constructing for quick heating, the less this resistance. Another advantage of heat

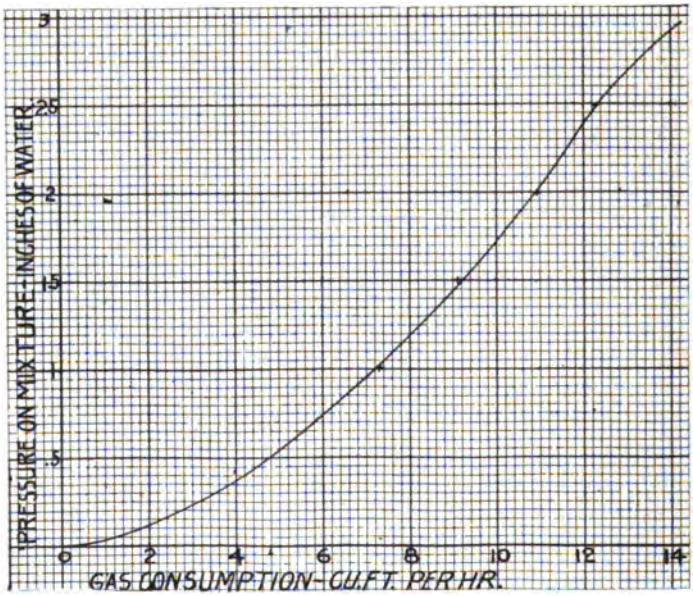

Fig. 41.—Rate of combustion of tubular type cook stove top burner having 35 holes, each $^1/_{16}''$ in diameter, discharging under square stemmed mushroom plugs, shown in Fig. 3, and provided with perforated Nichrome radiating plate.

storage in the incandescent bed is inherent to all intermittent heating such as the heating of laundry irons, which may thereby absorb heat for a time faster than it is being generated by drawing on the bed storage, and which always heat faster on the surface combustion burner than on a common burner of equal gas consumption, one trial showing that with two irons on a surface combustion burner an ironing woman could

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do as much work as with three irons on the bunsen, the former consuming about half the gas that the latter used, heating the iron in less time.

In applying these surface combustion burners a new study of service conditions is necessary, as they have some characteristics not possessed by the old burners that permit and even demand adaptation of burner design to service. There will always be some where quick heating is important, in toasters perhaps, others where heat storage is important, top burners that are much used and likely to receive spillings, or intermittent service, and likewise others that will demand the smooth self-supporting surface of the bonded diaphragm, which is operative in all positions and which has properties all its own.

The application of the bonded diaphragm to general service conditions is a problem in itself, as the localization of combustion is not so readily controlled under wide ranges of mixture pressures within the limits imposed by the ordinary domestic gas service. All such diaphragms except those of very great porosity and, therefore, necessarily thick, will heat from the outside inward, and in all the heat will work back, the combustion zone following until back flash takes place under some supply pressure and time of heating. Assuming that general service apparatus will be operated at a variable rate and so variable pressures, then the localization of combustion by diaphragms is not to be depended upon but they are still useful as baffles and radiators when placed over a hearth, such as described, and which latter insures localization. Placing a bonded diaphragm over such a hearth as, for example, that of the cook stove top burner, it will on ignition heat from the outside first; the combustion zone will then work down and through it until a back flash occurs and the combustion zone locates between the hearth and bottom face, extending from each hole into the diaphragm a little way if it lies directly on the hearth. As the heat works back unevenly, due to non-homogeneity of voids and size of grain, there will be at the moment of ignition below it only one hot spot, all the rest of the bottom and the hearth being cold. Up to this

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moment the outer surface has been hot and radiating, but now the heat will be practically all absorbed by the hearth and lower space until they become incandescent, and in this period the top radiating surface will cool and then slowly recover its temperature, after which it will operate indefinitely without change. The time it takes for the outer surface to begin to radiate, and for the back flash to occur, are both dependent on the relation of porosity to pressure or rate of supply, but the

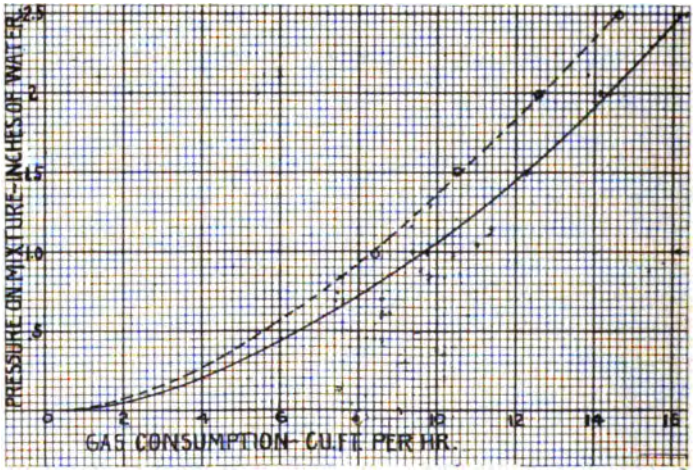

Fig. 42.—Rate of combustion of cook stove top burner having 35 holes, each $^1/_{16}$″ diameter, discharging to bonded diaphragms. Top curve, diaphragm of Norton alundum mixture. Bottom curve of English fire brick mixture.

time of recovery after back flash is largely controlled by diaphragm uniformity. If the combustion zone works back equally fast all over the diaphragm the bottom face will be hot all over when bottom ignition takes place, instead of only one spot, and so the top temperature will be recovered most rapidly. A great many small diaphragms of all sorts of grain materials and bonds have been tried and all abandoned in favor of alundum, which has been prepared by the Norton Co. to whom considerable credit is due for the spirit of co-operation displayed in opening up a new field, absolutely without data.

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Without reciting the details, it may be noted that satisfactory results are obtained with Norton alundum diaphragms fed through the self-cooling mixture holes, and set over the discharge hearths. These are structurally quite strong if the bond used is not intended for very high temperatures, in which case they are delicate but still useful for some purposes. Two con-

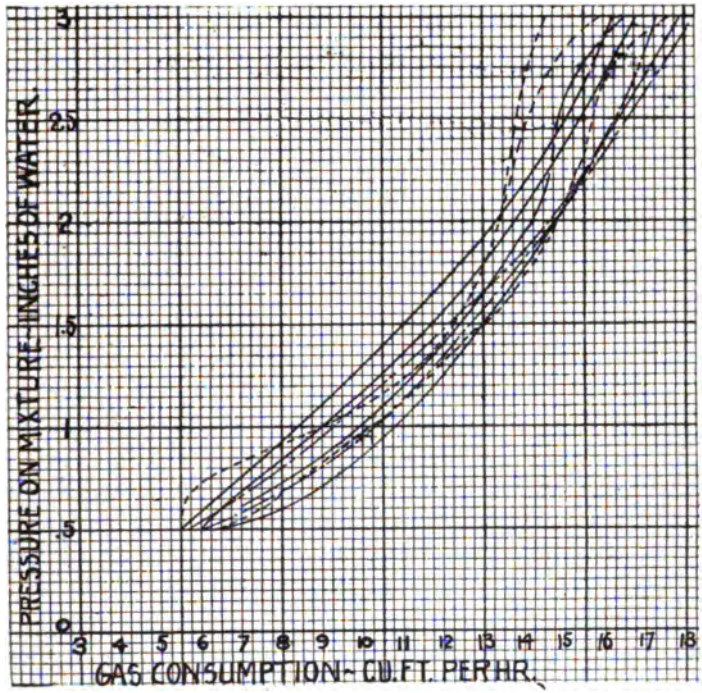

Fig. 43.—Rate of combustion of cook stove top burner having 35 holes, each $^1/_{16}$″ diameter, discharging through Norton alundum diaphragms of different construction. Each diaphragm $5^1/_8$″ diameter and $^7/_{16}$″ thick. Variation in curvature shows transfer of main resistance from feed holes to diaphragm.

sumption tests of such diaphragms set in the hearth over 35 holes, $^1/_{16}$ inch diameter, the porous part being 4 inches diameter and ½ inch thick, are given in Fig. 42, comparing a Norton alundum diaphragm of No. 4 grain with an English

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fire clay diaphragm, which latter fused in time on the hearth side, the former remaining unchanged. In Fig. 43 are given the same results for a series of alundum diaphragms 5⅛ inches diameter by $^{7}/_{16}$ inch thick, set over the same hearth after enlarging, to permit it. These were of four sizes of grain, No. 8, No. 6, No. 4 and No. 2, and three different processes of working and with each designated on the curves by numbers 0.5 and 10, associated with the grain size in number per inch of wire mesh, through which the grain passes. Change of curvature indicates that the main flow resistance has been transferred from feed holes to diaphragm.

The time of back flash and recovery of surface temperature varies considerably but in the best the whole time is about 5 minutes, but in some cases has reached 15 and even 20 minutes. The time of recovery varies from 3 to 12 minutes, the better diaphragms requiring the lesser time, all at pressures of 1½ inches of water.

Auxiliary Apparatus.—Any burner or furnace intended for laboratory use where operators have sufficient skill and understanding of cause and effect, need not be supplied with any special appliances for proportioning air to gas in the mixture, or for changing the mixture pressure as service conditions require it and, therefore, any of the many standard fans and blowers may be used for compressing air alone or air and gas separately with a hand adjusted cock in the air and the gas pipes supplying each appliance. This is by no means the case, however, with some industrial and with all domestic appliances. Where an industrial furnace operator is more or less constantly engaged in managing one furnace, he can be taught to make adjustments of hand valves if provided with the ordinary water column water gauge and a small sampling burner, but this is entirely out of the question for the ordinary woman in the home or chef in a hotel, as these either cannot or will not adjust anything beyond turning the cock that regulates the heat and, it must be confessed, sometimes not even this. For domestic service, including that of hotels and restaurants, it may reasonably be expected that they operate a single cock

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for each burner to regulate the heat, but maintenance of mixture proportions essential to surface combustion processes must be automatic and fool proof. This at first, like some of the other questions taken up, looked like a difficult problem, yet it seems to be working out in a thoroughly satisfactory way. Automatic mixture proportioning has been accomplished by two devices which working together carry out the fundamental method, which is proportioning by equal pressure drop on an air and a gas orifice, having areas in the desired proportion. Regulation of air pressure to an equality with that of the gas supply available at the appliance will bring them to a control cock having two ports with areas in the desired proportion and by suitably large pipes or small port openings, these ports determine the flow to a common mixture outlet, and the proportions will remain constant so long as the principal resistance to the flow of both is in the cock ports. This is accomplished, first, by sufficiently large supply pipes, but it is necessary also that the ports bear a suitable relation to the burner opening so that while the pressure drop through the burner is large enough to establish the desired velocities for localizing the combustion zone, there is also some drop of pressure through the ports themselves. In other words, the combined area of the ports in the wide open position must never be so large as to build up in the mixture chamber a pressure equal to that in the air and gas supply pipes. This does not involve any serious drop through the ports; 0.2 or 0.3 of an inch of water is ample, and less will do if necessary, but the more there is the more definite the proportioning and incidentally the smaller the valve needed. To permit of an adjustment to changes of gas quality one port may be made of fixed size with the other adjustable, but in opening and closing both must vary in constant ratio. It is not expected that users will make this quality adjustment, but rather the gas men who make installations and, of course, in any one district a setting will be found good for the average air requirement of the sort of gas supplied, the variation in which is never large enough to seriously interfere with the operation on this mean setting.

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Wherever the gas is uniform or substantially so in air requirement, this gas quality adjustment can be eliminated and the ports fixed at the proper value, once for all. One successful cock of this sort is shown in the sketch, Fig. 44, and shown photographically in Fig. 45, complete on the right and in various stages of dissection at the left. This has two plugs keyed

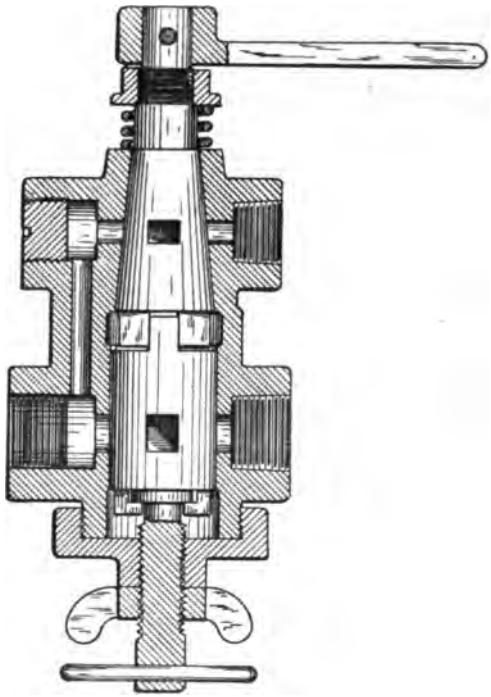

Fig. 44.—Sectional view of double ported mixing valve, with adjustment for ratio of air to gas.

together so as to rotate together, but otherwise free, one, carrying the small gas port, is tapered and spring seated for tightness, while the other, carrying the air port, is cylindrical, and has an axial adjustment for length of effective opening to adjust for gas quality. Both plug ports are aligned with the casing ports so as to absolutely open and close together. With

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this cock the user regulates the burner exactly as has been the case of common burners controlled by single ported cocks.

It is necessary, however, for the satisfactory working of any form of double ported cock, intended to maintain constant proportions of air and gas while controlling the total quantity of flow from zero to a maximum, that the air and gas approach at equal pressures so that the drop in pressure to the common mixture pressure be equal, and this may be accomplished by regulating the air pressure to that of the gas, or conversely. The former has been used as most satisfactory, and in accordance with it the air delivered by the fan is passed through a diaphragm regulator carrying a damper valve in the

Fig. 45.—Double ported adjustable mixing valve shown complete at the right and in various state of assembly at other points.

main air passage. This damper is rotated by a crank and connecting rod, fixed to the meter leather diaphragm, the weight of which is balanced by a spring or dead weight, if horizontal, but is to be neglected if operated in a vertical plane. The delivered air pressure is caused to act on the bottom of the diaphragm while the local gas pressure acts above, both sides being dead ends, that is, not swept by any current there is little tendency to dry the leather. All changes of gas pressure vary the diaphragm load and move the damper to the position to re-equalization promptly and positively so that no matter how local gas pressures may vary, the air automatically follows and the mixture quality remains what it should be. The construction of this regulator is shown by the sketch, Fig. 46

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and the two photographs, Fig. 47 showing one size of regulator complete, and Fig. 48 showing it partly dissected.

Air under pressure is always necessary for the operation of these surface combustion appliances but the pressure need be no more than is necessary for good regulator action, for which about 1 inch water drop is desirable. Air pressures of this order of magnitude are easily obtainable by fans and preferably are electric driven, though not necessarily. If

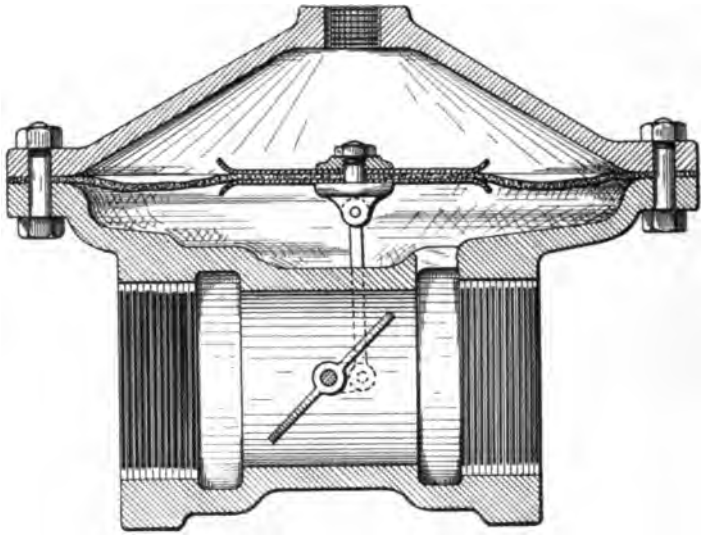

Fig. 46.—Sectional view of air pressure regulator for maintaining air pressure equal to that of gas.

the full available gas pressure is used, and this be three inches, then the fan should deliver at four inches of water, but very satisfactory operation can be secured at mixture pressures as low as 1.5 inch for full capacity, which would require less than 2 inches of gas pressure and less than 3 inches fan delivery. At such pressures the power requirements of the fans for ordinary appliances are very small, as may be easily calculated. For quick reference, the results of such a calculation are given in chart in Fig. 49 for a wide range of capacities

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and pressures, to which is added a scale for reading motor horse-power for any fan efficiency, and electrical input horse-power for any electric motor efficiency. For small sets the

Fig. 47—View of regulator complete, showing control damper held open by a nail.

Fig. 48—Air pressure regulator partly assembled, showing at the center connecting rod and crank for actuating the damper by the diaphragm movement.

fan efficiency will probably be between 30 per cent. and 50 per cent. while the motor efficiency will perhaps average 70 per cent. The power and current requirements are so low that

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any lamp socket will have electrical capacity enough to run any domestic appliance, even a large range, and in some cases several appliances operated as a group from one fan.

With these auxiliary appliances, it is possible to set up a complete surface combustion system for domestic service in either one of three ways; first, each appliance with its own fan and regulator and so completely independent except for connection to gas and electric service mains; second, central fan with distributing air pipes to each appliance with its own regulator, or third, combinations of appliances in groups. It is comparatively easy to see how central or group systems would work out for large installations, suitable for example, for hotel kitchens, but it is a matter of some interest to examine the independent domestic unit. The first of these ever constructed was made by converting one of the standard side cabinet ranges now on the market, using mixing valves that had been used elsewhere and a fan taken from a vacuum cleaner, in the absence of one of suitable capacity as to volume and pressure. The fan used was that of the Regina Cleaner in one casing with a G. E. motor and had an air volume capacity about four times what was needed, delivering at about 11 inches of water where four or five inches would have been sufficient and consumed 92 watts with all burners in operation. These things are stated to explain the somewhat crude appearance of some parts of this, the first self-contained surface combustion range ever constructed and put into service in a home kitchen. A number of views of it are given in the photographs, Figs. 50 to 53, so that all parts are clearly shown, except the check valve between fan delivery and regulator to prevent gas escape from the fan, should a burner be turned on when the fan is not in operation and which was not at first provided. It will be noted that the mixing valves or double ported cocks are fitted with graduates to guide the operation in adjustment, as the absence of visible flame, the ordinary guide, here demands a substitute. Auxiliary or secondary air openings into the oven are closed as now unnecessary, and if left tending to reduce efficiency by the air so drawn in and discharged hot to

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the flue. For the same reason the chimney vent is made smaller but the oven flue linings, which should not have been

Fig. 50—Corner view of first complete domestic range, self contained and ready for attachment to gas and electric service. Motor driven fan and regulator are shown on shelf, with all connections.

changed to provide for a flow of a smaller volume of gases

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at higher temperature with the surface combustion burners, than with the original bunsen burners.

Efficiency of Surface Combustion Appliances Compared with Bunsen.—As in other cases, it is here found that the abso-

Fig. 51.—Diagonal top view of first domestic range, showing solid cast iron top, with four top burners, refractory in place but burner grid removed.

lute and relative efficiency of surface combustion and bunsen burner appliances is not a constant thing but varies with conditions and, therefore, any discussion must be more or less limited in scope to give a correct impression. For this reason the figures obtained from test will be confined to domestic

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appliances operating on city gas, such as cook stove top burners,

Fig. 52.—Front view of first complete domestic range, showing dials on burner regulating cocks, here necessary in the absence of visible flame to permit operator to control burner.

broilers, oven, room and water heaters, all made by removing

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bunsen burners from standard appliances and substituting the new ones. Top burners were tested by taking the consumption

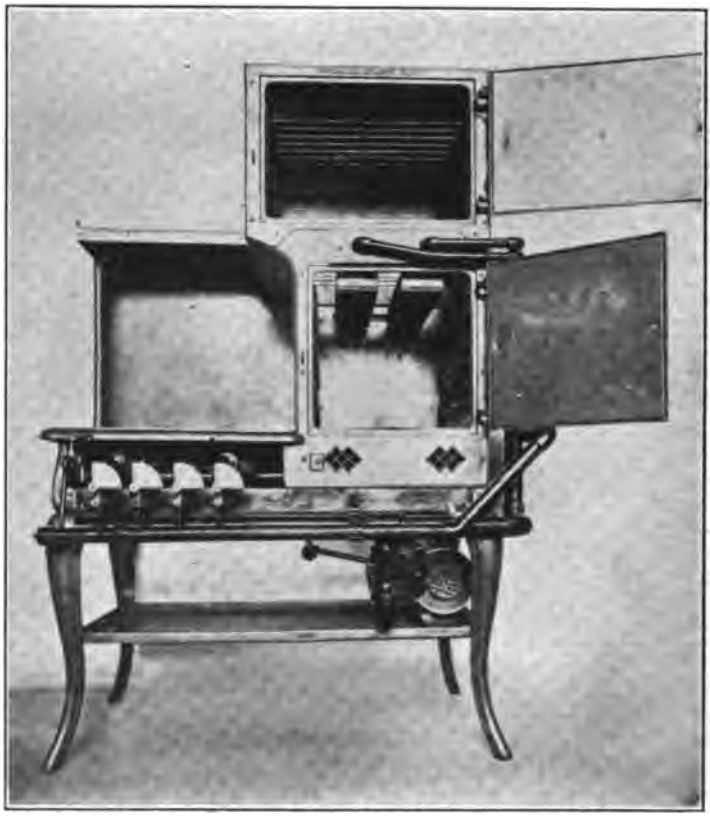

Fig. 53.—Front view of first complete domestic range, with oven doors open. Broiler and oven burners are visible, each being rectangular, mixture supplied to holes drilled in ribs between mixture chamber and hearth. Burners are suspended from front and back walls. The closing of the openings for secondary air is also visible on the lower door, no secondary air being needed for the surface combustion process.

and time to raise a weighed body of water to 200° F., from an initial low temperature and the same or identical vessels

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always open were used in all comparative tests. From a large mass of tests conducted with various bed materials and thicknesses, different sizes, shapes and materials of vessels, different distances between bed or flame and the vessel, at all sorts of gas or mixture pressures at various positions of the cocks and with various stove tops or burner ring construction, the figures do themselves vary so much as to be at first perplexing to one seeking some definite general conclusion on the relative value of the two systems. Careful analysis, however, reveals some order from which conclusions follow relating results to conditions. The first of these is that with identical conditions or as near so as the differences in the systems permit, the surface combustion burners always do an equal amount of heating of the water with less gas than the bunsen but how much less seems to be dependent on the construction of burner, stove frame and water vessel. Perhaps the most important of these external conditions is the vessel itself, and however queer this may at first seem, an explanation is available. If the vessel be large, of good conducting material, like copper or aluminum, and containing a large amount of cold water, it would approximate the heat absorber of a gas calorimeter and could take up a very large amount of the heat being generated at a given rate. On the other hand, if the vessel has a small heat absorbing surface in proportion to the rate of combustion and be made of poor conducting material then there is less chance of heat being taken up by the water, other things being equal. Size and material of vessel placed over a burner developing heat at a given rate do, therefore, determine to some extent the rate of heat absorption, but also the rate of heat dissipation from its sides, both the submerged and exposed part, and the water surface. This last factor is also more or less influenced by the extent to which the vessel is filled and the air drafts blowing on it. It thus appears that a great deal depends on the vessel and its filling, but as many detailed figures are always confusing the results of two vessels only are given in this connection. One of these is a cylindrical tinned iron saucepan, about 8 inches in diameter and equal height, and the

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other a smaller tapered pressed steel enameled saucepan, about 6½ inches in diameter, both tested on New York City gas, over burners consuming 15 cubic feet per hour, the bunsen burner being of the Crane construction and the surface combustion having a 4⅜ inch hearth with 20/64 inch to 24/64 inch material, ½ inch deep and covered at the edges by a cast iron ring with vents between it and the vessel ⅛ inch wide. For equal amounts of heat taken up by the water the relative consumption was as follows:

$$\text{Bunsen burner consump.} = \begin{cases} 1.44 \times \{\text{Surface combus. / Burner consump.}\} \text{ with large iron pot.} \\ 1.66 \times \{\text{Surface combus. / Burner consump.}\} \text{ with smaller enameled pot.} \end{cases}$$

These same two burners turned down to a simmer, using the enameled pot, as near as could be judged by the eye keeping the water just at the boiling point, the consumptions were bunsen 5.2 cubic feet per hour and surface 2.42 cubic feet, giving the ratio of 2.15.

The average of the two other series with enameled vessels on Westchester, N. Y. gas company, a thick silica bed surface combustion stove, grid top, 15 cubic feet per hour, with a G. G. A. Co. bunsen burner, gave consumption ratios of 1.71 and 1.75. A different surface combustion burner, that designed for quick metal heating becoming normal in less than one minute as compared with three or four minutes for the above burners, and illustrated in Fig. 40, gave a ratio on N. Y. C. gas of 1.80. This last was also fitted with a grid top, the enameled vessel being held about ½ inch above the bed.

These are high values and indicate a large fuel saving as may be seen from the following figures. Assuming a bunsen burner to be consuming 15 cubic feet per hour, then to give the same heating effect in a cooking vessel, the surface combustion burner for consumption ratios of 1.8, 1.7, 1.6, 1.5, 1.4 and 1.3, would require from 8.3 to 1.15 cubic feet per hour, saving from 6.7 to 3.5 cubic feet gas per hour while doing the same work. The high ratio above reported as actually attained may not be under favorable

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conditions and low values have frequently been found, in one case lower efficiency with a certain surface combustion burner and top construction than with the bunsen but this fact pointed out the mistake in construction which, when corrected, resulted in high ratios. As has already been pointed out, the size of vessel is important but so also is the heat dissipation from the top. In one case a solid stove top was used with circular openings to take the burners and quite low efficiencies were obtained, as low as 1.2, but it shortly appeared that most of the hot gases were escaping along the underside of the cold top instead of rising around the vessel, due to bad construction. A simple substitution of a grid that allowed the gases to rise with no other change raised the ratio from 1.2 to 1.68.

It may easily happen that service conditions will arise that will demand constructions that are not highly efficient, as for example, whole cast iron tops for intermittent service, in the interest of cleanliness, so that a commercial stove construction will probably be a compromise. The best judgment that can now be made is that, taking into consideration all these conditions, there may be expected a consumption ratio of about 1.55, bunsen to flameless or 0.65, flameless to bunsen, which indicates a saving of about 35 per cent. of what is now being used though it is possible according to actual tests that it may be as high as 45 per cent.

It has previously been stated that the expected savings from the surface combustion process were to be derived first from the elimination of the excess air now required of all bunsen burners, and second by the superior penetrating power of radiant heat in warming bodies from the fire. The influence of these two together is well shown in all the preceding relative consumptions but perhaps nowhere quite so well as in the case of the simmering test where two fifteen foot burners were turned down to keep the water just at the boil for about one hour, which raised the consumption ratio from 1.66 to 2.15. This is a splendid demonstration because in the turned down condition very much more cold air rises with the hot flame gases to the pot bottom in bunsen burners than when

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they are on full while there is no change, whatever, in this respect with the surface combustion burner. The difference above is, moreover, largely due to excess air because at the turned down condition the surface combustion burner bed was only faintly radiant. The minimum effect of this excess air influence is perhaps best obtainable from a comparison of two water heater tests made on identical coils of the Vulcan heater, one as constructed with standard bunsen burners and the other with a surface combustion burner substituted, but without other change. Both were operated to heat the water in a standard 40 gallon copper tank, equipped with thermometer and the results are uncorrected for radiation from it or pipes. The bunsen burner gave an efficiency of 70.4 per cent., while the surface combustion burner gave 82.3 per cent., a ratio of 1.17, the flue gas temperature of the bunsen being 248° F. against 309° F. or 61° higher, for the surface with its excess of 12.3 per cent. efficiency. Of course, a properly constructed surface combustion heater can easily be made to yield as close to 100 per cent. efficiency as may be desired, so these figures are given not to show what may be expected of such, but purely as a measure of the excess air influence when it is reduced to its lowest value in the bunsen equipment and which is entirely eliminated by surface combustion. Another measure of excess air influence is given by the figures for a comparative top oven test in which an upper oven was heated by burners below, intended primarily for a lower broiler oven. Figs. 50-53. As originally equipped with bunsen burners this top oven required 19 cubic feet of gas per hour to maintain at its center a temperature of 480° F., as against 13.5 cubic feet, a ratio of 1.4, when surface combustion burners were substituted, with no other change than the closing of the secondary air openings, linings which should have been changed being left in place.

The direct value of the radiant heat developed by surface combustion burners is shown most clearly in test of such apparatus as a broiler, or a radiant room heater, Fig. 31. Tests have been made in such broilers by taking the consumption

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for the proper cooking of steak and chops, both thick and thin, chicken, squab, fish, lobster, and toast, under the direction of competent chefs, and comparing with that required for the same carefully measured and weighed, in bunsen burner broilers. For this purpose the Crane bunsen burner broiler was selected that has cast iron fingers heated to a dull red by the flame and so has more radiant heat than other types not so provided though more commonly used. This was done to provide the most vigorous bunsen burner competitor available as a basis of comparison for the surface combustion burner and while results varied in specific instances the general average was very close to a consumption ratio of 2. This means that surface combustion broiling can be done with about half the gas now required on the bunsen burner type with feeble radiation and less than half required by others. The quality of the work done is uniformly better though it must be confessed that opinion differs somewhat here, never going so far, however, as to charge the surface combustion broiler with inferior work. The intense radiant heat which, of course, is under control permits the thing to be cooked to be placed from 6 inches to 10 inches away from the burner, promptly sears the outside and prevents the escape of flavoring juices, make the side that is cooking not only clearly visible but illuminates it so well that the operation can be perfectly carried on in a dark room.

This gas saving of 50 per cent. or better for radiant operations like the broiling reported above, is confirmed almost identically by the tests on the radiant room heater which was compared also with the Vulcan which carries a perforated cast iron plate attaining a dull to bright red by the heat of a bunsen burner below. Heat was here measured by the temperature rise of a measured body of water in a flat sheet metal box placed in front, far enough away to escape contact with any hot gases. The consumption for equal amounts of heat thus thrown out are almost exactly twice for the bunsen compared with the surface combustion. It may be said, therefore, that surface combustion domestic appliances can save

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in all directly radiant operations about half the gas required by the good bunsen appliances and in other cases like top burners and ovens an average of about 35 per cent. to use a few round numbers derived from actual tests in laboratory and kitchen. The above figures are for continuous operation and are reduced in some cases by intermittent work such as involves the lighting of a burner for a few minutes and then turning it out almost as soon as it gets warm. For such service as this efficiency is not so important as a quick heat and if less time than 1 minute be available one present type burner can be retained in each stove for it, reserving for the surface combustion burners the large gas consumption work where gas savings are equivalent to appreciable sums of money.

At this point the question naturally arises as to when the saving of gas becomes large enough to pay for the electric current consumed by the fan and in what time the net saving will pay for the increased cost of surface combustion appliances over bunsen. The answer to the last question is to be found only when it is known how much the appliance will be used, as the fixed charges per hour of use depend on the number of service hours per year and in this respect the case is similar to plant operation. If a domestic range is to be used one week per year it matters little how efficient it may be and the cheapest thing available in first cost is the thing to buy. On the other hand it will take a very short time to pay for the extra cost of an appliance that is used every day and doubly so if operated many hours per day, especially if the service requires considerable gas. Calculations could be given for all sorts of hypothetical cases but as anyone can make them for conditions that are important to him they are here omitted, but one case is included, however, for illustration. Suppose a domestic range with a full capacity consumption of 100 cubic feet per hour were operated three hours per day and three hundred days or 900 operating hours per year at an average rate of 50 cubic feet per hour with such distribution of various burner service as corresponds to an average saving of 40 per

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cent. of what a corresponding bunsen range would require. It may also be assumed that the latter would cost the consumer $35 and the former $50 and that gas costs $1 per 1,000 cubic feet and electric curent 10 cents per kilowatt hour. The surface combustion range would consume per year $50 \times 3 \times 300 = 45{,}000$ cubic feet of gas, while the corresponding bunsen would consume $\frac{45{,}000}{1.00 - 0.4} = 75{,}000$ cubic feet so that the saving of the former over the latter is 30,000 cubic feet, worth $30 per year. From this is to be subtracted the cost of 900 hours of electrical supply, which must be estimated. This can be calculated from the power charts given and it will be found that for very low efficiencies of fan and motor not over 0.5 ampere at 110 volts or 55 watts should be ample. In fact actual measurement of the Regina vacuum cleaner set, illustrated on the first range, Figs. 50 to 53, which had a delivery pressure twice and an air volume about four times what was required, required 92 watts with all burners in operation and 90 with none, proving the excess capacity and the probability of operating with fans and motors designed for the service on much less than half an ampere.

Assuming that at the start no efficient fan and motor be available and that the absurdly high consumption of 90 watts would be required for the necessary 10 cubic feet of air per minute at 4 inches to 5 inches water pressure, the electrical cost of operation would be $10 \times \frac{90}{1{,}000} = 0.9$ cent per hour, or $8.10 per year. This makes the net saving in operation $30 — $8.10 = $21.90 per year, and as the excess of first cost was assumed to be $15 it would be paid off completely in 600 hours of operation, or if uniformly distributed in 8½ months. One short way of disposing of the electrical cost is to consider that the gas saved by a single top burner will more than pay for the electric current to operate the entire range so that for all burners in operation in excess of one the electrical current costs nothing. That this statement is

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justified is indicated by the following, assuming the inefficient fan and motor that costs 0.9 cent per hour to operate is replaced by a better set, more suitable in size and design. If the service of a standard 15 cubic foot bunsen top burner is equal to a 10 foot surface combustion burner (ratio 1.5) the gas saving is 5 cubic feet per hour, which is worth $5 \div \frac{1,000}{100} = 0.5$ cent per hour. If the range had four top burners, one jumbo, and two broiler oven burners, and the ratio 1.5 applied to the whole consumption, then for the bunsen range the hourly gas would be $(3 \times 15) + (3 \times 20) = 105$ cubic feet, against $(3 \times 10) + (3 \times 13.3) = 70$ cubic feet for the surface. For this gas, the latter would require $\frac{6 \times 70}{60} = 7$ cubic feet per minute at 4 inches water. This corresponds to an air horse-power of $\frac{4 \times 5.2 \times 7}{33,000} = 0.0044$. With a fan efficiency of 50 per cent. the motor horse-power is $\frac{0.0044}{5} = 0.0088$ and for 75 per cent. motor efficiency the electrical horse-power input is $\frac{0.0088}{75} = 0.0117$. This is equivalent to $0.0117 \times 746 = 8.76$ watts which at 10 cents per 1,000 is worth 0.0876 cent. Thus the electric cost for the whole range is only 0.0876 cent per hour, while one top burner saves in gas 0.5 cent per hour. This shows how conservative is the general estimate above, that the gas saving at one burner will more than defray the expenses for current for the entire range, for under the conditions named the gas saving at one burner is five times the cost of current for all of them. The vacuum cleaner fan used on the first range consumed ten times the current that was really necessary yet even so, two top burners save enough gas to pay for all the current.

In the following table there is given a series of equivalents

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in gas saving, cubic feet per hour, the value of which just balances various values of electrical horse-power requirements of fan, which will be found convenient for reference.

GAS SAVING NECESSARY TO JUST PAY COST OF ELECTRIC CURRENT EXPENDED FOR FAN OPERATING SURFACE COMBUSTION APPLIANCES.

Electric H. P. required by fan	Equivalent watts	Equivalent amperes at 110 volts	Equivalent amperes at 220 volts	Current at 10 cts. per KW hour	Cu. ft. gas per hr. costing same as electric current at $1.00 per 1,000 cu. ft. gas
0.01	7.46	0.06782	0.03391	0.0746	0.75
0.02	14.92	0.13564	0.06782	0.1492	1.49
0.03	22.38	0.20346	0.10173	0.2238	2.24
0.04	29.84	0.27128	0.13564	0.2984	2.98
0.05	37.30	0.33910	0.16955	0.3730	3.73
0.06	44.76	0.40692	0.20346	0.4476	4.48
0.07	52.22	0.47474	0.23737	0.5222	5.22
0.08	59.68	0.54256	0.27128	0.5968	5.97
0.09	67.14	0.61038	0.30519	0.6714	6.71
0.10	74.60	0.67820	0.33910	0.7460	7.46
0.11	82.06	0.74602	0.37301	0.8206	8.21
0.12	89.52	0.81384	0.40692	0.8952	8.95
0.13	96.98	0.88166	0.44083	0.9698	9.70
0.14	104.44	0.94948	0.47474	1.044	10.44

It is hoped that this review of the development of surface combustion will show that it is now possible to design rather than merely invent apparatus, and that such apparatus as commercial conditions may require may now be produced in no more time than is necessary to decide on the models to be manufactured and the production of an initial stock, but there is no intention of leaving the impression that the work of development is finished for it is only just fairly started, and should be continued with corresponding improvement in appliances for the next half century.

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DISCUSSION.

The following questions were asked, which were answered by Dr. Lucke:

DR. LUCKE (New York City): We are prepared now to have a little heart to heart talk about these things, answering and asking questions, and after everybody is satisfied,—we intend to satisfy everybody—then we will arrange to have the audience pass up right and left and have a close look at the appliances that have been in operation all the time. After the discussion therefore will all those to the right of the center pass up to the right hand group of appliances and the rest to the left, the two groups are absolutely identical. Now, the questions. This is always the best part of a meeting.

A MEMBER: What is the durability of the burner?

DR. LUCKE: I do not know. I have run them six months and they are still as good as they were.

MR. JAMES FERRIER (Rome, Ga.): I wanted to ask you why not circulate water around a tube?

DR. LUCKE: If I understand you rightly, your idea is to circulate water around the mixture feed tubes. Water would improve the cooling of these passages, but it is good enough now, so we don't need the water.

MR. FERRIER: I think we will need it.

DR. LUCKE: Then we will use it. When we come to large areas or very high rate of combustion as may be desirable in some industrial operations, for example heating a furnace requiring 20 or 30 square feet of very hot surface there might be some difficulty about getting a good circulation of air underneath. Of course, we would use water in that case, but in these domestic appliances it is very desirable that no water be introduced.

A MEMBER: Will a change in gravity of the gas cause any trouble?

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DR. LUCKE: I do not think so. Of course, that would change the velocity of flow, and it would therefore to some extent vary the proportions in the mixing valve, but the amount of variation will be so small as to be unobservable except by very accurate tests. The ordinary user would not know anything had happened.

MR. J. D. VON MAUR (St. Louis, Mo.): Will the operation of the range be quiet or will it be noisy as we hear it now?

DR. LUCKE: I do not know. I think it will be a good deal more quiet than it is. I want to make it so and I think I can. These are just the first ones.

MR. WALTER R. ADDICKS (New York City): They are more quiet than the original ones now.

DR. LUCKE: We have made a great improvement in that respect. I do not see any reason why we could not get them absolutely silent. The one thing that is making most of the noise is the motor driven fan, and if you have any electrical friends just persuade them to make me a quiet motor.

MR. G. W. THOMSON (Chester, Pa.): Why does the name surface combustion apply to this method?

DR. LUCKE: A very good question. That is the key note of the whole process. If gas itself without any air mixture were discharged through openings like my finger, there would be a tremendous volume of flame. Gas burning alone would give a big volume of flame, the flame itself would fill much space. By using premixed air with the gas the flame volume is reduced. The total cubic feet occupied is less and less until just at these combining proportions the flame volume becomes zero and is replaced by a surface instead. Then those (refering to the appliances) will be length and breadth of flame without any thickness, so it is surface combustion.

A MEMBER: What is the temperature of the flame?

DR. LUCKE: I do not know, and so far as I know there is no way of measuring it. I would like to know. When we attempt to measure with any platinum or platinum alloy re-

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sistance or thermo couple thermometers they melt. Optical pyrometers are entirely useless for the purpose, since the flame is underneath something that you cannot look through.

MR. W. R. ADDICKS: What is the probable minimum temperature?

DR. LUCKE: The probable minimum temperature is somewhere around thirty-three or thirty-four hundred F, over three thousand degrees Fahrenheit.

MR. R. W. POLK (St. Louis, Mo.): Where is that temperature?

DR. LUCKE: Right where the flame is.

MR. POLK: On the surface?

DR. LUCKE: Where the flow velocity is equal to rate of propagation, and if you want to know exactly where it is in any appliance put in some granulated fire brick, leave it there for a moment, and shut off the gas and then it will be found to have fused to a lump just where the flame was.

MR. POLK: That is not the temperature at the outer surface?

DR. LUCKE: No, sir; the temperature at the outer surface is very much less than that. The temperature on the outside surface is the result of a balance between the heat that reaches it and the heat that gets away from it by radiation.

MR. JOHN B. KLUMPP (Philadelphia): Can you blow it out, Doctor?

DR. LUCKE: Not I. Seriously speaking I believe these fires cannot be blown out by any wind or draft and even are quite unaffected by blowing that would put out a bunsen.

MR. J. B. KLUMPP: What would happen if the motor should stop running?

DR. LUCKE: If the motor stopped, and the air supply ceased the gas would continue to burn at the same place with a lazy smoky flame and thus give a signal of that fact. No harm would result except to soot things up.

A MEMBER: Suppose the pressure should become excessive?

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DR. LUCKE: Do you mean the gas pressure?

A MEMBER: The air pressure.

DR. LUCKE: The air pressure. It would blow out.

A MEMBER: Could it get back into the gas pipe?

DR. LUCKE: Could the air pressure get back into the gas pipe? Not with any fan. We use the fan for an air supply, because fans cannot give high pressure, but if we thought the service conditions were such as to involve any possibility of a little excess air pressure, we would add another check valve. We already have a check valve on the fan outlet, so in case the operator turns on gas without starting the fan first—of course, they always do that, you know—then the gas cannot blow out through the fan. If we thought the service conditions were such as to involve the building up of a higher air than gas pressure, due to a failure on the part of our diaphragm regulator, if that is what is in your mind, a little light check valve on the gas line would stop a reversal of flow. So far we have not believed there is any necessity for it. If anybody wants it it can be put there, and that would make insurance doubly sure.

MR. J. D. VON MAUR (St. Louis, Mo.): You say the excessive flow of pressure would blow the flame out. Suppose that happened when there was nobody in the room? Wouldn't the gas escape into the room?

DR. LUCKE: Yes, sir.

A MEMBER: What is the chemical composition of that porous baffling material used in the top of the burner?

DR. LUCKE: There is no particular secret in that. I notice several periodicals seem to think it is the real secret of the process. This is not true. Anything that will not melt and will not crack up under the heating will do the business. What we are using here now is fused silica, which is a very permanent material, works splendidly; if you like aluminum better, all right, it can be obtained black or white; mourning or half mourning.

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A MEMBER: Is the life of the baffling silicon indefinite?

DR. LUCKE: Silica is quartz, and it is fused to changes in physical but not its chemical properties. The natural quartz or flint stone will on sudden heating crack; it would all crumble into powder after a while, but if it be fused in an electric arc it may then be dropped molten into water without seriously cracking. It loses its expansion characteristics. It has, what you say, almost a zero co-efficient of expansion.

MR. WALTON FORSTALL: Are these burners on the market, and if not, when will they be?

DR. LUCKE: Yes, but for such information I refer you to a commercial man. I am not a commercial man. I do not know how to buy and sell things. I only know how to make them.

MR. R. E. SLADE (New Orleans, La.): Is there any trouble with grease or dirt stopping up the holes?

DR. LUCKE: Grease cannot stop up the holes unless it be spilled on cold. What would happen then I do not know. Dirt might fill up the holes, but so far we have not had any trouble of that sort except in shipment, when these things were shipped down here they were shipped complete, and we found when they got here some holes were dirty from the banging they got on the railroad. After they have been set up to operate they do not seem ever to change.

A MEMBER: Have you found sufficiently refractory material to hold the silica in place?

DR. LUCKE: We are using a high-grade of fire-brick now and we find for the low rate of combustion used on these domestic appliances that it is good enough. It would not do at all for a high temperature furnace like that for small crucible melting. For that purpose we found the best thing to be alundum cement; to avoid shrinkage of the cement, it can be mixed with alundum grain and if the proportion of cement to alundum grain be adjusted so that the cement just fills the voids between the grain by measurement it will not shrink at all. It is very permanent under high temperature.

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A MEMBER: What I meant was the materials you are using here, that is the metal?

DR. LUCKE: You mean that screen?

A MEMBER: Yes.

DR. LUCKE: When this burner with loose beds is put vertically or upside down of course we use a screen. That is just because it is convenient. That screen as used here is of nickel and chromium with some iron alloy, about eighty per cent. nickel and twenty per cent. alloy. It is supposed to be good permanently for any temperature up to 2,000 degrees F. I have had some of it in operation for about six months, and it does not appear to be injured. We can, of course, bond all that silica or alundum grain and make a porous brick and eliminate the screen entirely. I do not like to do that myself. However, if you like it, we will make it for you. It might be struck by something and crack, and I think perhaps that would be worse than bending the wire. It is just a matter of taste. We have reached the point where we can make things to suit people's taste, and that is quite some progress.

MR. WILLIAM MCCLELLAN (New York City): Have you any knowledge of the proportion of the radiant effect as in this improvement compared to the decrease of excess air.

DR. LUCKE: Yes, sir. You will find some data in the paper. You will find a report of a test of a pair of water heaters, one Bunsen and the other surface, with absolutely identical coils at about the same amount of heat per hour. The difference between their performance is due almost entirely to a change in the excess air, the elimination of the excess air. For the ratio of their performance which is recorded there is the direct measure of the excess air effect. Then for another case where you have both excess air and radiation involved subtract the excess air effect from this water heater data and the rest is the radiant effect. Have you the idea? If you do not see it I will explain it to you later.

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A MEMBER: You spoke of the combustion receding into the refractory surface. Does that cause any loss in the heat radiation?

DR. LUCKE: No, it only delays the time of reaching the permanent condition; that is all. The more material there is to be heated the longer it takes the burner to reach a steady state, as I have pointed out. The flame will ultimately locate at the same place but take longer to get there. For a domestic range we have to cut down the mass of material to be heated to a very small amount. This type of burner has only about three-sixteenths of an inch layer on top, a very small amount, and they will heat to proper working conditions in less than a minute. I do not know exactly what the time is, but somewhere about a minute.

MR. CHARLES O. BOND (Philadelphia, Pa.): What is the lowest gas pressure at which it is successfully worked?

DR. LUCKE: That is a question of the size of the hole. With holes one-sixteenth of an inch as these are the burner has been turned down for an indefinite time after being heated up to the highest temperature and operated at two-tenths, by cutting down the holes to something smaller than one-sixteenth, something in the neighborhood of one-sixty-fourth, the flame will not flash back at all, no matter how you cut the pressure down. We do not do quite that far, because we do not like the holes to be any smaller than necessary on account of the inconvenience, dirt might collect more in a little hole than a big one. These will all run at two-tenths or less. By cutting the size of the hole the minimum working pressure can be made as small as wanted.

A MEMBER: Have you attempted any heat balance; have you made any measure of efficiency?

DR. LUCKE: Hundreds of them. On top burners the efficiency is between sixty and seventy per cent. On broilers I do not know what it is, because I do not know the thermal equivalent of a beef steak.

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MR. STANNARD (Denver, Colo.): Do these ranges cost any more than the ones that are used now?

DR. LUCKE: They will.

MR. W. R. ADDICKS (New York City): What proportion of the additional cost is in that electric motor?

DR. LUCKE: Almost all of it.

MR. J. M. MOREHEAD (Chicago, Ill.): Gentlemen, this question of surface combustion has been one which up until to-night I think we knew very little about. It is a new ground. There was no way we could find out about it, for there was nobody we could ask. They say trying experiments is asking nature questions. It is very hard to get a definite answer. Nature is very elusive. It is hard to pin her down and get a definite answer to a definite question. Experiments are generally slow. They are always expensive and sometimes dangerous. I think that Dr. Lucke has given some very definite answers to some very definite questions he was asked about surface combustion. He has been a pioneer in this business. He has extended the frontier of our knowledge and he is to be congratulated on what he has done, but especially I think that the association is to be congratulated on the fact that Dr. Lucke has carried us with him beyond what until to-night was our frontier of knowledge in the combustion of gas, and I want to move that the association shows its appreciation by voting a vote of thanks to Dr. Lucke for the information which he has imparted to us to-night, and through us to the entire gas industry of the United States, and, I will say, without any detriment to the lecture which we heard once before, that in view of the progress since then he is extending information to the entire world. And I move, gentlemen, that a vote of thanks be extended to Dr. Lucke.

MR. STANNARD: Motion seconded.

THE PRESIDENT: You have heard the motion which has been seconded more than once. All in favor of it say aye.

(Motion carried unanimously.)

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THE PRESIDENT: Dr. Lucke, it gives me great pleasure to extend to you the thanks of the Institute for coming here and giving this lecture. I appreciate fully what it means to you to have done so, and I appreciate the months of work and careful investigation you have made of this subject. We thank you. (Applause.)

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DEPRECIATION: ESTIMATED AND ACTUAL.*

A paper by Alexander C. Humphreys, M. E., Sc. D., LL. D., representing the American Gas Institute, and presented at the Jubilee Meeting of the Institution of Gas Engineers, Great Britain, June, 1913.

The American Gas Institute having accepted the gracious invitation of the Institution of Gas Engineers to present a paper at this meeting, which is intended particularly to celebrate its fiftieth anniversary, I have been designated to represent the sister society for this service. I appreciate the honor thus conferred; and this sense of appreciation finds emphasis in the fact that my long-time friend, Sir Corbet Woodall, is the Institution's President this Jubilee year.

I have chosen as my subject "Depreciation," so-called. This is a subject of importance to the owners and managers of all industrial properties. It is of particular importance to the owners and managers of public service properties. In connection with rate-making cases before commissions and courts, it is of vital importance to-day to the owners and managers of public service properties in the United States. Within the limits of a single paper—perhaps extended beyond the bounds suggested by a kindly forbearance—I cannot hope to meet satisfactorily all the many and complex questions which have come to be included or involved in the ambiguous term "Depreciation." Certainly, as used in the United States the term is not self-explanatory. This inability on the part of those discussing moot questions to agree upon the meaning of terms and forms of expression is at all times a fruitful source of otherwise unnecessary disagreement. Perhaps this is particularly in evidence in the United States. I know in advance, therefore, that through one cause or another, partly on account of the magnitude of the subject and my inability to give adequate expression to my views within the limits required, I shall not now succeed in avoiding all misunderstanding.

* Reprinted from the *Transactions of the Institution of Gas Engineers* (Great Britain), 1913.

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Necessarily, what I have to say is of more direct interest to an American audience. But part of what follows should be of interest to all owners and managers of public service properties; and in view of the fact that there is no inconsiderable amount of British capital invested in American public service properties, this discussion may be found to be of direct interest to many on your side of the Atlantic. In view of the spirit of unrest which is now in evidence all over the civilized world, and the readiness with which additional laws are placed upon the Statute Books of the United States, it is of the utmost importance that those who are responsible for these properties should be more nearly in agreement as to the most effective lines to be followed in their honest efforts to secure full protection for the investments entrusted to them.

If the many and complex questions involved in depreciation are to be solved so as to do justice both to the investor and the purchaser of service, there is required on the part of all concerned the most competent, comprehensive, and judicial study and treatment. While this responsibility must rest upon all who can or do exercise influence in the settlement of these questions, particularly must the responsibility rest upon the lawyers and experts representing the companies. In certain cases these representatives of legitimately invested capital have not sufficiently mastered the questions involved to qualify them to meet effectively their great responsibilities. This is peculiarly a cause for concern because the commissions and courts have of late years had thrust upon them for adjudication many novel questions; and so they need at our hands all that we can furnish as to general theory and special conditions. Here it is necessary to distinguish between hypothesis and theory. The theories adopted must include all the accepted teachings of experience.

While looking and hoping for, and confidently expecting, such a revision of public opinion as will give the public service corporations more even-handed justice than has been

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indicated of late in certain cases, this hope and expectation should rest upon the determination on the part of those most directly concerned to do all that is legitimate and straightforward to this end. Certainly it is the duty as well as the best policy of the representatives of the companies to be frank in their statements of fact and bold in the presentation of their opinions, provided those opinions have been formed with the rights of all in mind.

We must believe that, in the great majority of cases, the commissions and courts are doing their best, as far as time and training permit, to arrive at just decisions. But without wishing to express disrespect for our commissions and courts, certainly we must not be too ready to accept their opinions as the final word on any technical question. Some of our lawyers and experts are too ready to accept court opinions and decisions as final. The fact that on any of the questions we have to consider we can find court opinions varying through a wide range should furnish a sufficient corrective to this subserviency of mind. Certainly we should constantly keep in mind that, at least on many of the technical questions involved, we engineers are more competent to form a correct judgment than are the lawyers or judges.

For instance, I am not prepared to change my opinion as to the strength of cast-iron pipe as ordinarily used for the distribution of gas because the late Justice Peckham, of the Supreme Court of the United States, in handing down the unanimous decision of that court, in the celebrated New York Consolidated Gas Company's case, included in his opinion the statement that one feature of the law under consideration could not be enforced against the company because a pressure measured by a column of water 2½ inches high would burst the cast-iron pipes used to convey the gas.

This may be taken as an exceptional error. But this case of the Consolidated Gas Company was one of vital importance to our public service corporations and we may assume that it received the most careful attention of the Judge to

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whom was assigned the duty of making the more specific study of the evidence and of writing the opinion of the court. Judge Peckham was an able judge and a fair man, and yet he made an error which an illiterate but specifically trained foreman of a street gang could not have made. If Judge Peckham could make such an error, why should we blindly accept the opinions of commissioners and judges simply by reason of their official position?

Are we not further warned against a too subservient attitude of mind in this connection when we find our commissions and courts holding widely different opinions on what appear to be comparatively simple points of law? Where there is a direct question stated with all the facts arrayed on both sides, I see no reason why the engineer is not as competent to express a sane opinion on the law as a judge or lawyer is competent to express a correct judgment on some technical question in engineering or accounting. I feel quite sure that in many such cases I could do as well on the law questions as Judge Peckham did on the question of the strength of the ordinary cast-iron pipe.

I could cite many other cases to support this proposition. I have in mind a statement presented over the signature of the chief statistician of one of our most influential state public service commissions, in which nearly a million dollars was deducted from the operating expenses of a certain company because the money was paid for taxes. Those of us who have to supply from income the money to meet the tax collector's claim will find little comfort in the statement of commission or court that this item of cost is a "fixed charge," and therefore something different from the other items of cost—such as wages, salaries, coal, etc. I do not find that this classification assists me to pay the bill or to reduce the cost per 1,000 cubic feet of the gas sold.

Much of the error to be found in the opinions and decisions of the commissions and courts is due to the acceptance of hypotheses as theories, which fail to meet the definition

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of theory because they exclude the necessary limitations of practice. One reason for misunderstanding in connection with depreciation, so-called, is that some of those charged with responsibility fail to appreciate, either wholly or in part, that the questions involved are not the same in the case of a so-called monopoly, subject to governmental regulation, as in the case of a commercial undertaking engaged in an avowedly competitive business, and which only has to reckon in this connection with its owners. This statement is not to be misinterpreted by those who, through ignorance, are ready to discover dishonest motives actuating those dealing with the public.

To take a simple example: In a close corporation engaged in a competitive business, the managers of which are liable only to their own stockholders, it may be considered right and wise to distribute only a portion of the net profits and to apply, wholly or in part, the surplus profits, particularly in extra prosperous years, to writing down the plant account. In the past this has been regarded as conservative practice. Even though the proprietors received no additional stock to represent the increase in assets, they knew that their proportional shares in the ownership of the property remained unchanged. But to get a fair return on the full investment, the dividends were necessarily based upon what appeared to those uninformed as an excessive dividend rate. The fact that the plant and business had been extended by the investment of earnings—the dividends paid as averages through the years probably having been moderate —does not in any way vitiate the ownership of the stockholders in these extensions. If all the net profits had been distributed to the stockholders, and then the additional capital as required had been handed back to the company in payment for additional stock, the facts would not be changed. Yet by this last method there could have been no question as to the rights of the stockholders.

In the case of public service corporations whose rates of

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charge are subject to regulation, however, this practice raises questions, and so subjects the stockholders to unnecessary hazard. In the State of Massachusetts, this practice of writing down plant account—charging extensions against income and also debiting lump sums to loss and gain and crediting plant account—has been much in evidence. This was to be expected from the generally conservative tendencies in New England. The State of Massachusetts was the first to place its gas companies under the supervision or control of a commission. This commission was not given the powers that are now conferred upon our state commissions; but it exercised a very restrictive influence as to stock and bond issues and rates of return, and its decisions in this connection have not been notable for consistency. The case is made harder for the stockholders because the law of this state prohibits stock dividends to cover surplus earned.

The effort of this writing down of the Massachusetts companies is at once apparent by a study of the annual reports of the Commission of Gas and Electricity. These companies, instead of showing "watered" stock, show a total capitalization which does not represent the structural value of the plants, to say nothing of certain overhead charges and "going value." One of these companies shows a capital which is equal only to 35 cents per 1,000 cubic feet of annual sales. If we add to the capital stock as issued the "notes payable" issued to cover *part* of the extensions and for which the company may hope to be allowed to issue stock, the total is only $1.64 per 1,000 cubic feet of annual sales. The cost to reproduce the plant and business of this company would exceed $5 per 1,000 cubic feet of annual sales.

In a case recently decided by this commission, the gas company involved (Attleboro) had been paying 12 per cent. dividends on a capital which was equal to $1.10 per 1,000 cubic feet of annual sales. The commission in its opinion says: "Its capital, in proportion to its business, ranks lowest of the gas companies in the state." This company had no

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"notes payable" against extensions; so presumably the Commission took this into account in making the comparison with other companies, and particularly the company to which I first referred. But notwithstanding the company was paying only 12 per cent. on its capital as issued, which would have been about 2.6 per cent. on a capital equal to $5 per 1000 cubic feet of annual sales, the commission reduced the price of gas, at the same time enunciating certain rules which clearly must operate to confiscate portions of the company's legitimate investment.

I simply introduce these cases to point out that what may be conservative policy in the matter of writing down plant account to cover "depreciation" in the case of a company managing its own business, it is a fatal error to write down assets below their legitimate investment cost where we are subject to the opinions and control of those who have had insufficient practical experience. It may be easy to understand that the public, in the persons of the consumers, are willing to take something for nothing, but this does not prove that the investor can rightfully be required to accede to such a demand; and if he is so treated he will in future be slow to furnish capital for new public service undertakings or for the further development of those already in operation.

Not only does this unscientific and haphazard method of "writing down" of assets work a direct injury to the stockholders of the company involved, but it works an indirect, but very potent, injury to the industry as a whole by furnishing opportunities to the adroit and unscrupulous statisticians to make comparisons which appear convincing on their face but which have no value when analyzed. Unfortunately many such comparisons are accepted on their face in the absence of competent analysis. Here we must not forget that the public and the irresponsible politicians are on the watch for high rates of dividends, without regard to the relation between total legitimate investment and total face value of bonds and stock.

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It may create some surprise if I make the statement, as I do, that not a few of our well-established steam railroads have so maintained and so extended and bettered their plants from income that they could not now pay 5 per cent. annually on the reproduction cost of their physical assets alone. I believe this would be true of our railroads taken as a whole. Or we can say that the total par value of the stocks and bonds of all our railroads does not equal the cost to reproduce their physical assets. It is not unlikely that this statement will be received, even in certain quarters in the United States, with doubt and perhaps derision. But I venture to believe that some of our public service commissioners, those competent, fair, and courageous, who might have laughed at this statement a few years ago, would now, as the result of their experiences, be willing to lend it their support.

In our gas and electric rate-fixing cases—in the first instance generally tried before the State Public Service Commissions—we are called upon to meet commission and court decisions which are far from being consistent. In general, the service rate of charge must be one which allows of a "fair return" (whatever that may mean) upon the "value" (whatever that may mean) of the property "usefully employed." Perhaps the one element which is included in all decisions is the appraised value of the plant. Some courts have defined this as the cost to reproduce new, less "depreciation." This is the dictum which the public service corporations are most generally called upon to face.

Many questions are here introduced as to what constitutes the reproduction cost. Shall the unit prices be those quoted at the time of making the appraisal? As this might work for or against the corporation under fire, it is sometimes suggested that the average prices for the last five or more years should be used. Here there is a fine field for argument, and especially on the part of the experts, lawyers, and others opposed to the public service corporations. A prolific

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source of debate is the question of pavements over mains. If the mains were laid before the pavements, should the company claim the cost of pavements as adding to the cost to reproduce new? If the company were selling its property, whether the pavements were laid before or after the pipes, the price would be enhanced by reason of the mains being under pavement.

Some commissions and courts include the value for sale of the property as a whole as an element for consideration. Others like the California Commission, exclude this element from consideration in a rate-fixing case. To be on the safe side the companies must be prepared to meet any and every contention which has received any measure of approval at the hands of any commission or court, no matter how inconsistent these several contentions may be when introduced in the same case. The company may have to face a selection of all the elements least favorable to its case, irrespective of consistency. The opinion of the Massachusetts Commission in the Attleboro case, recently decided and previously referred to, is notable for its inconsistencies.

There are other items to be considered in the making of an appraisal which are prolific sources of disagreement, either as to their admission or as to their measure, such as preliminary expenses, interest and taxes during construction, omissions and contingencies, engineering, organization during construction, insurance, compensation of general contractor (including his expenses), "going value," etc. Fortunately there is a fairer disposition now in evidence as to the admission of these "overhead charges," though there is still ample room for improvement in the interest of justice to the investor. The Public Service Commission of the Second District of New York has done more than its share in developing sane and fair methods in these and other connections. The Wisconsin Commission also has shown a disposition to be fair and independent in its statements of principles, though it has not always been keen to be guided by the principles so enunciated.

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It is not my present purpose to discuss at length these and other items which we have to consider in our rate-fixing cases. I may say, however, that these items, of which depreciation is one of the most important, if not the most important all things considered, are to-day questions of vital importance to many of our public service companies. I have referred to these matters in the effort to disclose the atmosphere in which we have to fight for justice.

The subject of "depreciation," as connected with the making of appraisals for rate-fixing cases, has been greatly complicated by being involved with the estimates made to cover each year's share of the cost of final renewal or replacement of plant; this to be included as one of the year's items of cost of operation. This estimate is made, and the annual debit to loss and gain and credit to a reserve account are made, solely for the purpose of spreading more evenly over the years of the plant's service the cost of that portion of maintenance which is not covered by current expenditures for repairs and minor renewals. This estimate of final renewals is supposed to include the elements of physical decay, obsolescence, and inadequacy.

Unfortunately, as I think, we have not infrequently included in this estimate some reserve for extraordinary hazards outside of final renewals. This introduces an unnecessary complication, particularly when it is claimed that the plant has depreciated to an amount represented by the balance to the credit of this depreciation reserve. By segregating the charge for final renewals from contingencies and hazards, we would be in a position to support more effectively our three claims—namely, the inclusion of an annual cost charge to cover final renewals; the inclusion of a reasonable charge for the creation of a limited reserve for contingencies and hazards; and the exclusion of a depreciation deduction from our plant appraisals in rate-fixing cases.

We will assume that the estimate of the annual cost of

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final renewals of the several parts of plant is made on the basis of a compound interest sinking-fund. The total amount required each year to be charged to loss and gain and credited to reserve will be made up of several amounts required to replace the several parts of plant at the end of the several expectations-of-life which we, in our wisdom or unwisdom, assign to each part of the plant. These parts will be grouped together according to the assigned expectation-of-life. The amount annually required for each group will be the sum which, accumulating at compound interest for the years assigned, will equal the cost of the plant—or the cost less such amount as we believe we can recover in disposing of the displaced parts of plant.

It is thus seen that the total amount credited to reserve each year is the sum of the amounts required for the several sinking-funds; the number of such sinking-funds being the number of different lengths of life we have assigned to the several parts of plant. This bringing together of the amounts required by these several sinking-funds is convenient in our accounting; but it has led to further complication by bringing into the problem the so-called "average life" of the plant. The use of this term is constantly creating the impression that the plant lives to the term set by the average life and then has to be renewed as a whole. Nothing could be farther from the truth.

To show that in a sinking-fund scheme there is no length of time which is mathematically the average-life, it can be pointed out that this term will vary in length with the rate of interest by which the fund compounds. For instance, I have before me a very simple expectation-of-life table in which there are assumed only five groups of parts of plant as follows: Group "A," 10 years, $25,000; Group "B," 15 years, $50,000; Group "C," 25 years, $100,000; Group "D," 35 years, $150,000; and Group "E," 50 years, $175,000; total, $500,000. The true average-life found by dividing in each case the cost by the expectation-of-life is 28.378 years;

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whereas the so-called "average-life" for a 2 per cent. sinking-fund would be 28.2 years; for a 4 per cent. sinking-fund, 27.73 years; and for a 6 per cent. sinking-fund, 27.05 years.

To emphasize the point that this average-life should not be allowed to misguide us, and further that the sinking-fund is in fact a collection of sinking-funds, it may well be noted that in the life-table above given the several groups of plant will be renewed within the fifty years which completes the cycle, as follows: Group "A," 5 times; Group "B," 3 1-3 times; Group "C," 2 times; Group "D," 1 3-7 times; and Group "E," 1 time. Here it can be seen that while the term average-life may be convenient for use by those who understand the subject, it may readily lead into error those who have that little knowledge which is so dangerous.

This brings me to three points which must be kept constantly in mind in connection with the study of the problems in depreciation:

1.—The depreciation reserve, or, more correctly, reserve for final renewals, is set up for the purpose of spreading the cost of final renewals of parts of plant as uniformly as possible over the periods during which the several parts are expected to render effective service; thus obviating unnecessary fluctuations in cost of operating, and so making it more practicable to keep the rates of dividends as uniform as possible.

2.—The amount to be so charged annually to loss and gain and credited to reserve is based upon an estimate or assumption of the effective life of each part of the plant, considering the elements of physical decay, obsolescence, and inadequacy. There is here the opportunity for the exercise of the highest judgment, recognizing the difference between hypothesis and theory and keeping in mind all the limitations of practice. To cover the element of obsolescence, we must know the present

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state of the art and prophesy as to the future. As to inadequacy, we must estimate as to the future increases in demand for service. As to physical decay, we are limited as to the future by the character of the management, over which we may have no control. Necessarily, then, this estimate is subject to correction. It must be based upon certain assumptions; and these assumptions as to design, construction, operation, and accounting, must control so long as the estimate goes uncorrected. This should mean that the estimate must constantly be open to correction as additional general and specific experience is gained. It should also follow that no tables of averages are applicable to any specific case.

3.—The loss will not have to be met until the replacement actually is made. It is an accruing liability against an obligation not yet due. Hence, if we take out the year's share of the accruing liability, as the payment is not yet due, the fund should receive the benefit of interest accumulations until the time for payment arrives. So far as the plant's capacity for rendering efficient service to the buyer of service is concerned, it by no means follows that the plant has depreciated to the extent of the balance to the credit of the reserve, and that this amount, or any amount, should be deducted from the appraised cost to reproduce the plant new. On the contrary, the fact that such a renewal reserve is being maintained is the strongest argument that all that is possible is being done to provide against impairment of investment and impairment of service efficiency.

The liability to renew or replace the plant rests upon the proprietors; and here is the best indication that this liability is recognized and provided for.

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Let us now consider a case of appraisal of plant for rate-fixing. We will assume that the plant is being maintained in efficient condition through repairs and minor renewals paid for from current income; that final renewals are being made as required and the cost debited to the final renewal reserve; and that we are debiting each year to loss and gain and crediting to final renewal reserve the amount indicated by the estimate based upon the expectation-of-life of the several groups of plant. Of course, it is to be understood that where reserve is credited on account of liability for future renewals, when those renewals are made the expenditures therefor should be charged against reserve and not against the year's operating expense. I emphasize this point because some have been misled by thinking that we purpose to build up the reserve indefinitely.

Now let us further assume that the appraisal of plant for rate-fixing is in continuous operation, and that depreciation is to be deducted as indicated by our table of expectations-of-life for the several parts of plant, and as advocated, unfortunately, by some commissions and courts, and not always opposed by those responsible for the protection of investments. The result would be the eventual elimination of all the investment in plant. For as each life group of plant reached the age at which the tables declared it was to be renewed or replaced, the deduction for "accrued depreciation" would equal the original cost. So as each group of parts of plant came to the time for renewal or replacement, that portion of the investment would be deducted from the plant appraisal, and there would be no provision for re-establishing the assets, because expenditures for repairs, renewals, or replacement cannot, as a general proposition, be capitalized.

I say here "as a general proposition." I leave the way open for exceptional cases, such as the rapid and abnormal obsolescence experienced in the development of the electric lighting and electric railway industries. Here the allowed

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rates of charge for service were not sufficient to pay a "fair return" on the investment and maintain the integrity of the investment. To require the proprietors to meet the total renewal charge in such a case would spell confiscation.

Now let us consider specifically certain questions which are raised in our rate-fixing cases, and which trouble even some of the lawyers and experts appearing for the companies.

Question No. 1: If you are not willing to deduct for "depreciation" in your appraisals of plant, why do you claim the right to include an item for "depreciation" in the cost of gas?

Answer: The income from the operation of the property should first pay all items of operating cost, including administrative charges, taxes, and the maintenance of the integrity of original and supplementary investment. The cost of the final renewals or replacements of plant, as well as the repairs and minor renewals currently made, must, then, be paid for from income. This means that the cost of final renewals—or what is usually called estimated, accrued, or theoretical depreciation—is an item to be included first or last in the cost of gas.

As the cost of final renewals does not generally fall evenly on the succeeding years, we may estimate the cost thereof and divide it evenly over the years involved. Unless this is done, the cost for the year or years under examination may be below the average, by reason of the non-inclusion of the year's proportion of cost of final renewals and replacements. Or, it might happen, if there had been expenditures for final renewals or replacements far above the average, that the cost of gas might be unduly high. In either case, the rate of charge would be based upon an incorrect statement of average cost. This serves to explain why some companies are now properly including in their statements of cost an item to cover the cost of final renewals, although they did not include such an item before the days of rate regulation. The mere fact that the effort is made to spread this item of cost over the years involved is no argument one way or the other

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for a deduction for depreciation in the case of a plant which is being properly maintained and is rendering efficient service. This is a legitimate item of cost; and the item being acknowledged as a charge against income, the liability rests against the proprietors, whether or not a reserve is established, to meet this liability.

This point is well made in a brief on this subject submitted by Charles F. Mathewson, of the New York Bar, in the case of *King's County Lighting Company vs. The Public Service Commission for the First District of New York.* Mr. Mathewson was the trial lawyer for the company in the celebrated New York Consolidated Gas Company case. The brief now quoted from considers this question chiefly from the legal standpoint. It is the most logical paper on this subject I have ever read. Mr. Mathewson says:

> The proposition [to deduct "accrued depreciation" in valuing plants in rate-making] is so absurd on its face that it hardly needs discussion to show its fallacy. Why, aside from the question of "confiscation," should consumers, for exactly the same service, equally efficiently rendered, expect to pay less in the sixth year than in the first year, merely because some items of plant will (viewed at the sixth year) require replacement at a date in the future then nearer than such date was at the beginning of operation? As well might it be claimed, to repeat a homely illustration, that a farmer should regulate the price of the eggs which he sells, by the age of the hen which lays them—reducing the price of the product as the hen gets on in years. The reason he does not is that the service efficiency and operating value of the hen, as evidenced by the quality of the eggs which she lays, are not impaired by the fact that her life is advancing. That advancement may concern the farmer and possibly concerns the hen; but it in no manner affects the value of the eggs to the consumer, or justifies him in demanding them at a lower price than he paid at an earlier period of her life. The consumer of the eggs must expect to pay a sufficient price to afford a return to the farmer on his total investment in the hen during her life, *plus* enough more to enable the farmer on her death to replace her and thus keep his investment unimpaired. A farmer could hardly be expected to invest in hens for the purpose of supplying the public with eggs, if for a por-

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> tion of their life he was to receive a return on only a third or a half of his investment; and any such rule would simply compel the public to go without eggs until the regulating power (if such there were) saw fit to revise its reasoning. There is absolutely no difference in the economic principles applicable to the operation of a gas plant and the operation of a hennery, so far as concerns right to return on capital; and what is absurd in one case is equally absurd in the other. The fact that the rate of return in the one case is subject to reasonable regulation, and not in the other case, has no bearing on the main proposition.

This question can be further answered by the statement that, if the final renewals were so evenly distributed over the years as to make a practically uniform annual charge, there would be no occasion for a renewal reserve, and there would be no occasion for raising this question. For instance, suppose we bring into the shop for testing and repairing such a number of consumers' meters that the whole number in service is completely overhauled in sequence every five years. Each meter is examined, cleaned, parts repaired or renewed as found necessary, or condemned and replaced by a new meter. The cost of all this work, including the new meters to replace those condemned, is charged each year into the cost of distribution, and so into loss and gain.

Here there would be no need for any additional item to be included in operating cost to cover final renewals of this portion of the plant. The cost of maintenance and final renewals would thus be more accurately distributed over the years than by means of any estimate based upon expectation-of-life. Furthermore, the plant would so be maintained to the highest possible degree of service efficiency. Certain experts of reputation have, unfortunately, taken the position with regard to plant so maintained by approximately uniform renewals that depreciation should be deducted from the appraised cost to reproduce new.

As further examples we may consider the ties of a railroad or the poles of a telegraph company. The assumption has been made that these would have a ten-years life, and

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that one-tenth of the total number would be replaced each year. Then it has been assumed that the average *age* of these ties or poles will be five years, and so there is a 50 per cent. depreciation which, in a rate-fixing case, must be deducted from the cost to reproduce the plant new. As a question of averages, the statement may be correct. As a basis for deducting 50 per cent. from the investment in this portion of the plant, it is without the slightest warrant in equity or common sense. This procedure deprives the investor of return upon one-half of his investment in this portion of the plant, and so works confiscation. And this though the utmost that can be done is being done to maintain the service efficiency of the plant! And the service efficiency is the only feature in this connection in which the buyer of service has any just claim for consideration. A certain authority has recently stated that a railroad soon after being put into operation will suffer a depreciation of 15 per cent. and thereafter it can be maintained at 85 per cent. of its original cost by adequate current expenditure for maintenance.

In each of these cases, if there is of necessity a deduction to be made from the original cost to cover "depreciation," a deduction which cannot be avoided by entirely adequate expenditures for replacements, then an amount equal to the deduction for depreciation should be added to the appraisal as one of the necessary items of cost, on the same basis as interest during construction and the many other items other than material and labor as already mentioned. Certainly there is no reason, under these circumstances, including the maintenance of service efficiency, why the investor should submit to any such wholesale confiscation or to any confiscation, however small.

It may happen that the whole question of "depreciation" may be cared for by the approximately uniform annual expenditures for final renewals. This condition is not infrequently to be found in the case of properties which are scattered over a number of locations, or have been built at

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different times widely apart. We have such cases in the United States, and I have no doubt there are many in Great Britain.

Question No. 2: Having established a sinking-fund to cover accruing and accrued depreciation (final renewals), why, in a rate-making case, should you not deduct correspondingly from the reproduction cost (new) of plant?

Answer: Practically this is question No. 1 turned around; but it approaches the difficulty from another point of view.

It has already been shown that the final renewal sinking-fund is established to spread more uniformly over the life of the plant the cost of final renewals of the several parts of the plant. The establishing of the fund indicates a definite purpose to maintain the plant from income, and hence shows that there is no occasion to depreciate the investment in plant. This fund, whether invested in securities or additions to plant, claims its own earnings or interest accumulations to complete the amount required for renewals. Hence its earnings are appropriated in advance as a charge against income, and the fund cannot be taken as an offset to depreciation. If depreciation were deducted, the earnings from this portion of the investment indicated by the depreciation deduction would be eliminated, and so the investment to that extent would be confiscated.

Question No. 3: If plant extensions have been made from the accumulations in the final renewal sinking-fund, why should these additions to plant be included in the inventory of plant to be appraised for a rate-making case, and why should these extensions not be treated as duplications of capital investment?

Answer: This a special case under question No. 2. When the "depreciation" sinking-fund is drawn upon to pay for extensions or betterments, the amount is loaned from the credit balance of "depreciation" reserve, which balance is the accumulation remaining after the payments for the final renewals which have been made against the reserve. Here it is to be remembered that this reserve is being added to

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annually by the charges to operating cost and interest on accumulations, and is being reduced from time to time as the parts of plant included in the expectation-of-life table come to be renewed or replaced.

Then all parts of plant which appear in the inventory or appraisal as having been paid for from the depreciation reserve fall in one of two classes:

(1) Parts which have been installed as renewals or replacements, and are, therefore, in place of parts represented in the original investment, and hence to be included in the inventory as such.

(2) Parts of plant which have been installed as extensions or betterments, and which have been paid for by money borrowed from the depreciation reserve. These parts should, therefore, be included in the inventory and appraisal because they are not a duplication of investment, but represent additional investment.

As has been shown, the balance to depreciation reserve should be credited each year with interest at the rate agreed upon. The money so borrowed has to be returned when required for final renewals, and must be repaid from capital. In the meantime, the company has been able to defer the day for permanent financing. These extensions can be considered as capital investments; the amounts borrowed from depreciation reserve, with interest thereon, standing as a liability against the proprietors. In this connection, the point may be again made that, whether there is a depreciation reserve or not, the liability for renewals rests against the proprietors.

As to whether there shall be a depreciation reserve or not, concerns the proprietors, and in no way concerns the public or the consumer. In any case, the cost of final renewals must be paid from income; and it can work no hardship to divide this cost as uniformly as possible over the years of service. This could be done by estimating the cost per 1,000 cubic feet without necessarily making any journal entries. The journal entries, and all that follows, are simply

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steps in accounting which make for greater accuracy and permit at any time the regulating authority to check up the methods pursued. If the plant is not so maintained as to give efficient service, either by failure to make repairs and minor renewals from current income, or later to make final renewals, the liability rests upon the proprietors, and can be enforced by the regulating authority.

If the deductions were made from the appraisal of plant to cover neglected repairs or renewals, and then the deficiencies, under the orders of the commission, were made good, the investment would remain impaired, and so there would be confiscation. If the price were fixed on the basis of this valuation, so reduced by depreciation deduction, then the price so reduced would not be sufficient to give a fair return upon the entire necessary investment. If extensions to plant were made after this reduction in price, the price then could not afford a fair return upon this undepreciated additional investment. The final outcome would be, if this confiscatory procedure were continued, that the plants so affected would not be extended, and the public to be served would suffer. If it is claimed that the rate of charge would be increased to meet this restoration of the plant, the answer is that it is much easier to reduce than to increase a price, and especially so as to the service rendered by a public service corporation.

As a certain member of one of our most influential commissions said recently in this connection: "We are representatives of the people." It might be suggested that, as our public service corporations are largely owned by the small investors, either directly or through banking agencies, the commissions, if they are to protect all the people, should be encouraged to act impartially between the sellers and the buyers of service.

Our confidence as to the future is increased by the knowledge that some of our commissioners are strong enough and fair enough to take this position; and the number is increasing. One notable case can be referred to, of a man who went

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into office avowedly opposed to public service corporations, believing them to be what the interested politicians accused them of being, but at the end of his five years of very active service, publicly declared that he had found greater fairness, candor, and honesty with the corporations' representatives than with the representatives of the people.

Question No. 4: In the making of plant appraisals for any purpose, should present actual depreciation be measured by reference to tables of expectation-of-life prepared for estimating accruing liability for final renewals, together with the ascertained present age of the plant?

Answer: If what I have so far said is conceded, it follows that the accrued liability referred to cannot be ascertained by reference to tables of averages computed from the study of plants dissimilar in many ways. Such an estimate of accrued liability, to support any claim to accuracy, must be based upon a careful and competent study, preferably extended through years of the plant under examination.

If, then, we wish to know the condition of plant at any time, why refer to such tables? Why not examine the plant itself, having in mind its condition as to physical decay, obsolescence, and inadequacy? Certainly, if we desired to learn the cost of an elaborate structure, we would not consult the preliminary estimates of the architects when we could have access to the treasurer's final and complete records.

Were it not for the fact that many prominent engineers are following the practice of using so-called standard tables in estimating present depreciation, deducting in proportion to the age of the plant, I should not think it necessary to treat this question seriously. This method, reduced to its simplest terms, is something as follows: A plant is assumed to have an average life of fifty years. The average age is found or assumed to be twenty-five years. Result, depreciation 50 per cent., investment impaired 50 per cent.

Perhaps it is unnecessary to say that the men who err most radically in this direction are book-men, who have had little or no practice to balance their faulty or incomplete theories.

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In the United States, the professors of economics and statisticians are much in evidence at present; and many of these men are striking examples of the "blind leading the blind." The recklessness of statement indulged in by some of these men, depending as they do upon the reading of books, often each other's books, is simply appalling. It is still more appalling when we reflect that not a few of these men are teaching their destructive doctrines to the young men attending some of our prominent colleges and universities.

To determine the amount of actual depreciation of a plant presents many difficulties, and calls for superior capacity founded upon scientific attainments and broad and exact experience. This determination may be required in connection with a change in ownership, that it may be known what expenditures, in addition to the purchase price, are required to bring the plant up to the required productive capacity and efficiency. Or, it may be required to check up the accuracy of estimates on the cost of maintenance, including final renewals. Or, it may be required by a public service commission to test the justice of a complaint as to faulty service. In any case, the facts are to be learned by expert examination of the plant itself, having in mind physical decay, obsolescence, and inadequacy. If life-tables are employed, they should be used with the utmost caution, and then only as a most general guide, and never by those who have not had adequate experience as constructors and operators. Perhaps the greatest danger in these tables is that they encourage those who are incompetent to think they are competent.

Question No. 5 (a question recently asked): Assume a plant that has cost $100,000; its average life, 40 years. At the end of the first year's operation there has been charged to loss and gain $2,500 (100,000 ÷ 40) as the year's proportion of depreciation, and a satisfactory dividend has been earned and paid to the shareholders. Then, as the shareholders have received a satisfactory return on their $100,000 invested and have also had returned to them $2,500 of their

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principal, what right have they to demand a return next year on more than $97,500?

Answer: Like many of the questions asked by the cross-examiner, this question, either through design or failure to understand the principles involved, is based upon faulty premises, and involves an unwarranted assumption. Assuming that the proposition as to non-deduction for accrued depreciation is accepted, then if the average life were forty years, $2,500 should not be charged to loss and gain to cover the year's depreciation; but there should be charged such a yearly payment only as through the operation of a sinking-fund would be required to redeem $100,000 at the end of forty years—and this for the purpose of renewing or replacing the plant. The end sought is so to maintain the plant as to maintain the integrity of the investment. The maintenance of the plant includes repairs, minor renewals, and final renewals. In this particular case, the amount so required for a 4 per cent. sinking-fund would only be $1,050.

Whether or not $2,500 or $1,050 has been charged to loss and gain against income, this is not a return of part of the investment, because, when correctly estimated and computed, it is part of the cost of maintenance, and hence a charge against cost, quite as much so as repairs and minor renewals. [I apologize for repeating such a self-evident proposition, but it seems to be necessary.] Again, if the amount charged is $1,050, as it should be, this amount, and the succeeding payments, must be invested in one way or another so that the earnings or interest on the annual payments may also be added to the fund to produce the required $100,000. When we bear in mind that for a forty years amortization at 4 per cent. the forty annual payments only aggregate ($1.05 \times 40 =$) $42 per $100, and the interest accumulations have to produce the required remaining $58, perhaps we can better appreciate that the annual renewal reserve payments cannot work as earners of dividends for the stockholders; but they have their separate work to do for the stockholders in earning interest to be applied to the protection of the investment

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It is to be remembered by those who are puzzled by question No. 5 that the $100,000 plant must continue to be a $100,000 producer of service year by year. If depreciated to $90,000 at the end of the fourth year, only a $90,000 service should be expected then from its operation; at the end of the thirty-ninth year, only a $2,500 service should be required from its operation.

Over and over again the question is raised in one form or another: If the consumer has been charged for depreciation in the rates, why should he be charged again through failure to deduct for depreciation? The depreciation, or cost of final renewals, is part of the operating cost; and there would be just as much reason for reducing the investment because certain amounts have been charged into operating cost for coal, wages, salaries, etc., as there would be for reducing the investment in plant because the cost of maintenance has been included as part of that cost.

Finally, nothing that I have said as to the determination of actual "depreciation" is to be taken as an admission that in a rate-fixing case any deduction should be made from the appraised cost to reproduce plant new to cover so-called accrued depreciation, or, more correctly speaking, the accrued liability against the stockholders for final renewals or replacements. This is a liability resting against the proprietors; and they must be given the normal opportunities to meet this liability without in the meantime suffering confiscation of investment by anticipation of the dates when the several payments to meet this liability may fall due. It is the part of wisdom for the owners of properties to reserve from income *all* that may be required to preserve intact their property investments; but this establishes no reason for deductions for depreciation in connection with rate-fixing.

If, however, the public service companies are to be required by the commissions and courts to face a demand for deduction for estimated accrued depreciation, then ordinary prudence suggests that there should be charged up for such depreciation each year the amount found by dividing

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the cost of plant by the estimated average-life; that is, "straight line depreciation."

Let us hope that the Commissions and Courts may be convinced of the justice of the proposition herein presented, that is, estimated depreciation charged on the sinking-fund basis, and then no deduction from appraised value for depreciation so accrued on effective plant.

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INVESTIGATION

of the

Conditions Governing the Choice of a Proper Quality Standard for Artificial Gas

with

Conclusion and Recommendation

of the

Joint Committee on Calorimetry

of the

Public Service Commission

and

Gas Corporations

in the

Second Public Service District New York State

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March 6, 1913.

HONORABLE F. W. STEVENS, *Chairman,*
Public Service Commission,
Second District,
Albany, New York.

SIR:

On December 8, 1909 your Honorable Commission issued a circular to corporations engaged in furnishing or distributing coal gas, water gas and mixed gas within your jurisdiction, and appointed February 1, 1910, as a date for conference to interchange views on the necessity for a calorific standard and all questions necessary and incidental thereto.

On February 1, 1910, the representatives attending appointed a committee to co-operate with the Commission in the consideration of these questions, and thereupon your Honorable Commission appointed representatives to meet with this Committee. After a preliminary meeting on the same date, the representatives of the companies and of the Commission organized as a "Joint Committee on Calorimetry."

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Since that date the investigation of this subject has continued and the history of the work and matters relating thereto will be found in the report transmitted herewith.

In accordance with our instructions: "If there is anything in your conclusion that requires the action of this Commission in any way, we shall expect that it shall be reported to us, and we will take it into consideration as to whether it is the proper thing for the Commission to do," we would respectfully direct your attention to paragraphs 12, 26, 35, 37 and 41, of the report herewith.

We have the honor to be,

Very respectfully yours,

W. R. ADDICKS, *Chairman*,
T. R. BEAL,
M. J. BRAYTON,
H. H. CROWELL,
J. C. DE LONG,
A. H. ELLIOTT,
J. B. KLUMPP,
C. F. LEONARD,
WM. MCCLELLAN,
W. T. MORRIS,
R. M. SEARLE,
C. H. STONE,

C. H. B. CHAPIN, *Secretary*.

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REPORT OF JOINT COMMITTEE ON CALORIMETRY.

1. The first commercial distribution of artificial gas for illumination was in open luminous flames and quite naturally its quality was stated in terms of the most convenient unit at hand—the candle. With the introduction of the much more efficient mantle burner, and the increasing use of heating devices, the heating value of the gas became important. As a result, scientific men in both Europe and America have recognized that to continue the use of the candle power (illuminating) standard was, for modern conditions, illogical and unsatisfactory, and in lieu thereof have advocated the adoption of a heat unit standard. More than four years ago the Public Service Commission of the Second District of the State of New York noted the trend of development, and started an investigation of the actual conditions existing throughout the Second District. This led to the appointment of a Joint Committee on Calorimetry, composed of representatives of the Commission and of the Gas Corporations of the State.

2. This Committee, after three years of continuous research and investigation, having had the assistance of the laboratories of the Commission and of tests made at sixteen gas plants in the State, and the results of numerous experiments conducted elsewhere to aid it in its conclusions, now makes its report.

3. The object constantly in mind has been the selection of a standard for artificial gas which will enable the consumer to obtain the most value for the least money, and will enable the Company to obtain its profit at the smallest expense to the consumer. The interests of the consumer and the Company are one. This one interest demands a standard which will fit in with present economic conditions, which will permit the most efficient use of modern invention and which will conserve resources instead of wasting them.

4. The yielding of the open flame burner, the only device

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requiring the gas to have an illuminating value, is the first reason for suggesting a standard based on the heating value. The mantle burner is from four to eight times as efficient as the open flame burner, and its use reduces the cost of lighting to the consumer. As is well known, the light is obtained by heating a mantle of rare earths to incandescence. The gas needs only heating value because the burner is merely a heater for the mantle.

5. As in all heating devices the burner is adjusted so that the gas is completely burned and shows a blue or almost colorless flame. Consumers, if properly informed, would substitute mantle burners for open flames in practically every case. In addition to the greater economy there is greater safety in many cases and more effective illumination always.

6. In addition to modern gas lighting devices which require heating value only in the gas, there is a rapidly growing demand for gas for cooking and heating purposes. Artificial gas is being supplied in increased amounts for melting, tempering, metal finishing, drying, gas engines and hundreds of other industrial uses. Inventors are actively at work designing apparatus which will greatly increase this use. Heat storage furnaces for heating buildings economically with gas are proposed. Indeed it seems to be true that it only needs the design of proper gas-using apparatus to make gas the most economic means of transporting the heat content of coal. Under such circumstances to give artificial gas an expensive and unnecessary illuminating value is illogical and indefensibly wasteful.

7. The illuminating quality in gas, which, with the disappearance of the open flame burner becomes unnecessary, may become a costly feature if it must be added to the gas by a special process of enrichment. This enrichment is usually made by means of a petroleum oil which for a number of years was worthless for anything else and consequently was very cheap. But the enormous growth in the demand for gasoline for automobiles and motor boats has stimulated chemists to invent processes by which the enriching oils heretofore used by gas

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companies can be turned into light oils suitable for internal combustion engines.

8. Inventors of oil engines are perfecting their devices rapidly, which results in much more extended direct use of oil for power generation. Oil used in this way commands a higher price than when used for gas enrichment. The United States and other governments are resorting to increased use of oil fuel for war vessels, and their needs are so paramount that price is not a critical factor. (Reference: "The Production of Petroleum in 1911," U. S. Geological Survey, 1912.)

9. This sudden demand for enriching oil products by the people for pleasure and industrial purposes, and by governments for power purposes, and the consequent rise in the selling prices, has within a year increased the cost of manufacturing water gas from 10 to 15 cents per thousand cubic feet. In addition there is every reason to believe that the present price of oil is by no means the maximum, so that cost may operate in the future to require that enrichment be kept to a minimum. It was the presence of a large and cheap supply of enriching oil that made water gas commercial after the manufacturing apparatus had been made practical from 1877 to 1882. It is probable that the high price of enriching oils will make carbureted water gas useful chiefly for peak demands and as a reserve to retort gas and oven gas, which need no enrichment if heating value only be required.

10. The present rise in the price of oil would result in a condition seriously affecting the price of gas to the consumer if it were necessary for artificial gas to continue to have the present high illuminating value. Fortunately the availability of the mantle burner modifies the seriousness of the situation. It may be argued that gas oil has risen in price before and afterward dropped. It must be added, however, that the price never returns to its previous low figure. Moreover, as shown above, the present rise is due to plainly apparent and quite natural causes, and it does not appear that these causes will abate in force.

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11. In passing it may be stated that water gas must be enriched to be practical for community use. Retort gas (so-called "coal gas") has ample heating value and illuminating value to be distributed without enrichment to the community. Run of oven gas (by-product from coke ovens) has a large heating value without enrichment, but in candle-power is materially lower than retort gas.

12. It should also be noted that whatever reasons there may have been in the past for different standards for coal gas, mixed gas and carbureted water gas (16, 18 and 20 candle-power in New York State, Second District), they certainly are without force now, and only one standard is necessary or desirable.

13. Mere increased cost, though important and almost compelling, is not alone the cause for a change from a candle-power to a heat unit standard. As a matter of fact, when this Committee was appointed this feature could not have been in any degree a reason for changing the standard. The present standard actually retards the extension of gas service and as a direct consequence retards the development of communities.

14. Present development in gas distribution falls into two classes—first, distribution in comparatively densely populated large territories such as cities, with closely attached suburbs; and second, distribution of gas from one large central plant to a number of more or less distant communities with intervening territory in which there is little or no demand for gas supply. In either case the present candle-power standard is a burden. This is for the reason that because of temperature and pressure changes and friction in mains a part of the enrichment added to a gas to give it illuminating power drops out during transmission, and the loss becomes more and more serious as the distance of transmission increases. Higher pressures are necessary if the gas is to be transmitted economically for a long distance and it is impossible to avoid some exposure to low temperature. As a result either the gas must

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be given excessive candle-power at the plant, or it must be enriched after transmission so that the gas distributed after transmission may be up to standard. In either case it is sometimes difficult to make the operation of the system satisfactory and the cost increases to an amount which makes such distribution often commercially impracticable.

15. Within single areas or communities, extension of service is possible so far as the present law is concerned which requires inspections to be made about a mile from the works. This does not mean, however, that the same quality of gas can be supplied economically at the center and on the outskirts. The company undertaking to give standard service at all points must of necessity spend much more on its manufacturing and distribution cost because the average candle-power must be higher in order to make up the loss.

16. In the case of one large central plant distributing gas to a number of more or less distant and separate communities, the burden is especially heavy, for but one quality of gas can be ordinarily distributed from the plant. The long distribution system with its higher pressure and exposure to low temperature entails a very great loss in candle-power during transmission. In addition, the operation is likely to be difficult, because the enriching oils which condense in the system must be taken care of in larger pipes, traps and other devices and the labor cost of operation is increased on account of the maintenance and operation of these extra devices. With the increased cost of enriching oil it is probable that such extended distributions will not be possible without a serious increase in the selling price

17. Too small a community cannot support a gas plant of its own, if first-class service is to be given, ample financial support secured and adequate business and engineering superintendence supplied. For a long time the same conditions obtained in the supply of electricity but the problem of supplying the smaller community has been solved by the develop-

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ment of high-tension, long-distance transmission of power. By this means any number of small communities and intervening farm territory can be served from one large central station. High-pressure gas distribution bears the same relation to the gas industry as high-tension transmission bears to the electric industry.

18. As shown later, the loss in heat units in transmission due to pressure or low temperature is very much less than the loss in candle-power. A heat unit standard not very different from the heat unit value of gas at present supplied would permit gas distribution over long distances under pressure at a loss which would be in no sense burdensome. Such a result would permit, as soon as development could take place, gas service to many small villages and towns which it is quite impossible to supply under present conditions.

19. A further reason why a change from a candle-power standard to a heat unit standard is desirable rests on a broad economic policy. Even though oil were not increasing in price the present standard spells waste. It is a waste of resources and it is wasteful of money. Conservation of resources would demand that there should be no unnecessary resort to the use of oil for gas enrichment. It is wasteful to maintain a standard beyond what is required for efficiency and when the standard means an unnecessarily high cost. The public wants the best gas for the least money and it is to the business advantage of the Company to supply the demand. The present standards, under existing conditions, do not assist in attaining this desirable end.

20. Summarizing then, the movement toward a heat unit standard is based on three important factors:

1. Modern appliances for the use of gas require that it have heating value only. The open flame burner is rapidly disappearing on account of its inefficiency and expense.

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2. The present candle-power standard seriously impedes desirable distribution in extended communities and for long distances, and as a consequence retards community development. The rising price of enriching oils adds to the difficulty.
3. The present standards are wasteful of resources and unduly burdensome on the consumer and the Company.

21. In order to obtain accurate information on which to base the choice of a proper standard, particularly with reference to the needs of New York State, the Committee turned to a number of gas corporations of the State for assistance. Laboratories for calorimetrical measurements were established at sixteen different plants of the State and regular daily tests started. The instruments were checked first at the laboratory of the Public Service Commission at Albany. The cost of the apparatus and the expense of the tests were all carried as operating expenses of the plants where the tests were made. Constant attention had to be given by the Company's officers and their employees to the investigation, and the expenditure of time and money was not small. Results of this work make up the most valuable data that the Committee has in this report. In Appendix B will be found tabulations and curves showing the results obtained by the various Companies with comments and discussion in considerable detail (see also Appendix C). The monthly reports of the Companies summarizing their daily tests when received by the Committee were scrutinized closely for errors and critical features. Every effort possible has been made by the Committee to make sure that the work was being done with uniformity and accuracy. The co-operation of the traveling gas inspectors of the Commission was of marked assistance in this respect. As a final test on this point, a demonstration was held at Amsterdam, N. Y., at which all the calorimeter operators of the various Companies making tests were present. This gave an opportunity for a further demonstration in regard to uniformity

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and accuracy. The Committee feels confident that the results are accurate within one per cent.

22. Certain other important facts demonstrated by this experimental work should be mentioned.

23. It is known that a calorimetrical laboratory can be established at comparatively small expense.

24. Calorimetric measurements can be made with great accuracy by men with no special scientific training except experience in and attention to proper operating directions.

25. The calorimeter as a practical instrument is more accurate than the photometer. There is no uncertain feature in connection with its use as there is with the type of burner and standard unit of light used with the photometer.

26. From the test results no law could be discovered showing a relation between the candle-power and the heat unit value of artificial gas. The Commission's preliminary investigation indicated this, but the results, involving 6,738 calorimetric and 9,167 photometric observations, obtained by the Committee make it a demonstrated fact.[1] For this reason it would be very difficult indeed to state the heat value of artificial gas of a quality equal to the State standard for candle-power inasmuch as the Companies generally distributed gas above the legal standard, in some cases as much as 17 per cent. For the information of the Committee, however, two plants were operated close to the State standard. As the results in Appendix B show, gas meeting the State standard of candle-power would have approximately a monthly average of 585 B. t. u.[2] The question immediately arises as to whether this value should not be taken for the heating value standard of gas to be distributed in New York State. The

[1] Note Chart Appendix B, pp. 40-41.

[2] B. t. u. is the accepted abbreviation for the British thermal unit, which is the amount of heat required to raise the temperature of one pound (avoirdupois) of pure water from 39.1° F. to 40.1° F. The variation in the quantity of heat necessary to raise the temperature of a pound of water 1° F. is so slight for any temperature between 32° and 212°, that in general the B. t. u. may be safely taken as the amount of heat necessary to raise the temperature of one pound (avoirdupois) of water 1° F.

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several steps in the reasoning necessary to properly answer this question are important.

27. It is desirable that a new standard shall not differ greatly from the heating value of gas of the present legal standard. To have it materially less would require the distribution and use of a larger volume of gas in order to get the same useful effect. This in turn would necessitate radical changes in the selling price annoying to both consumers and Companies without benefit to either.

28. To meet a heat unit standard of 585 B. t. u. means that most Companies must enrich the product during a portion of each twelve months.

29. There are a variety of combination methods of making artificial gas from gas coal, anthracite coal, bituminous coal and oil, which are discussed in Appendix C.

30. Any enrichment is expensive and it has been shown above that it is becoming more and more so with the increasing price of oil. It is safe to predict that if the present price of oil continues, carbureted water gas will no longer occupy the important position that it has for some years past in the gas industry. Indeed, the idea is now taking firm hold that owing to the oil situation, with the practically inexhaustible supply of gas coal now in sight, the gas industry must depend upon coal gas of some sort for the bulk of its output and use water gas as a reserve. In any case excessive enrichment is useless and unsatisfactory, especially in connection with modern gas appliances. Gas unnecessarily enriched interferes with manufacturing processes, and when distributed to the consumer deposits carbon in burners and mantles and, as heretofore stated, the illuminants drop out in transmission, especially under pressure and at low temperature. Other things being equal, it will be to the advantage of consumers and manufacturers if enrichment is reduced to a minimum.

31. As shown later, with the most modern horizontal retort settings and machine stoking, coal gas from high-grade gas coals and with high yields of gas per ton of coal, without en-

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richment, varies in heat units from approximately 550 to 600 B. t. u. monthly average. If the general use of carbureted water gas as a staple product becomes impossible on account of the very high price of enriching oils, and must be replaced by retort or oven gas, and if the heat unit standard is set at such a point that the manufacturer will need the highest grades of coal in order to meet this standard or else be compelled to use high-priced enriching oils, it is obvious that the price of these higher grade coals will rise so that the very object of the change will be defeated. It is interesting to quote here from Bulletin 6 of the Bureau of Mines of the United States, published in 1911:

> "In a consideration of the various means whereby more economical and more efficient use may be made of the fuels in the United States, the possibility of obtaining for the production of illuminating gas other and cheaper fuels than the Pennsylvania coals demands attention. For the Government, as well as for private corporations and the householder, there can be no more economical and efficient way of using some coals than through the medium of illuminating gas. In the stove, gas reduces the labor cost of heat production and lessens the drudgery of the kitchen; burned in the Welsbach mantle, it is an excellent and cheap illuminant. In addition, the coke that remains after the gas has been recovered furnishes a smokeless fuel that has about the same heating value as anthracite. Hence any investigations that will indicate how local coals through proper treatment may be substituted for the higher priced and rapidly vanishing Pennsylvania gas coals will bring about lower prices for both gas and coke, and will also aid to conserve for use in metallurgical processes the coking coals of Pennsylvania and of other States.
>
> * * * * * *
>
> "There are few well-developed coal fields in this country that furnish coal satisfying all the requirements of

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illuminating-gas manufacture. Most of the coal used hitherto has come from Western Pennsylvania, the quantity supplied by other fields being relatively small. The introduction of gas-coals from new or little-known districts, because of the lack of necessary testing stations and of scientific study of the complex process of gas manufacture, has been difficult."

32. We must, therefore, think that it would be inadvisable to set the standard for artificial gas so high that the best coals only could be used. The standard should be placed so that average coals may be used without enrichment, and thus give the very greatest economic value to the consumer at the lowest cost.

33. Certain methods of operation are now being discussed that may be desirable, or even become compulsory under conditions which seem to be approaching. The disposition of the coke resulting from the manufacturing of coal gas has been in the past a serious problem to some Companies, and at a time when coke was used in cooking ranges since discarded for more desirable gas ranges. For this and other reasons it may be desirable in the future to manufacture a mixed coal and carburetted water gas, using substantially all of the coke as fuel in the water gas sets. If this becomes a general practice it may be desirable to lower the standard. Coke oven gas in which the coal is carbonized primarily to obtain coke for industrial purposes and the gas a by-product is also being considered in many places. Run-of-oven gas would require excessive enrichment if the present standard was in force. It it quite probable that should this coke oven gas be distributed in larger quantities it would be desirable to reduce the standard. Present data from these various processes show that it might be necessary to fix the standard at 525 B. t. u. or even lower.

34. It is difficult indeed, in view of the uncertainty as to just how fast certain changes in the conditions governing gas manufacture and distribution will take place, and as to what

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the final situation will be, to determine the proper value at which to set the standard. It has been shown that some time in the future the standard may have to be 525 units or lower. It has also been shown that, at present, the monthly average, even with the best coals and highest grade plants, may be as low as 550 units. All plants, of various sizes and locations, cannot become highest grade plants, at least immediately, and the smaller plants never. The best coals are not available to all, and if the demand is increased the price will rise. Notwithstanding these facts it is believed that the standard adopted must be close to the heat unit value of the present standard gas.

35. Taking all these conflicting factors into consideration, it is the judgment of the Committee that a total heat value not exceeding 570 British thermal units monthly average measured at the point where the gas leaves the manufacturing plant, corrected to a temperature of 60° F., and to a pressure of 30 inches of mercury, as measured by the rules of the Committee accompanying this report, is the standard which will best serve the interest of the people of New York State.

36. The standard suggested above is referred to the standard atmospheric cubic foot, *i. e.*, at 30 inches barometer and 60° F. It will be perceived that the only time a consumer would get the standard number of heat units would be when his meter was at 60° F. and the barometer was at 30 inches. Such conditions cannot obtain, however, with localities at different heights above sea level and with meters located in all kinds of places giving different and varying temperatures. Therefore, some average conditions must be chosen. These might be the average annual barometer and temperature if they could be obtained for each locality and a "local cubic foot" might be fixed on these terms. All such "local cubic feet" could then be required to have the standard number of heat units. This would be possible for a group of localities not varying too much from a certain average altitude. It would be very inconvenient however. A certain mass of coal

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gives a certain mass of gas at best economic yield, and the volume of the gas is solely dependent upon pressure and temperature. Therefore, if a "local cubic foot" is used, operators would operate differently at different altitudes and temperatures, even though using the same coals, oils and machinery. A comparison of detail methods of operation, the study of proper amounts of oil and steam, temperature of various parts of the sets or benches and other features, are sufficiently complex now without making them more so by introducing accidental atmospheric conditions. There could not be even a mere comparison of results by State authorities and others interested, in order to increase efficiency, until the results were brought to a common basis. In a State having largely different altitudes several standards might be required owing to the impossibility of making a uniform commercial gas in all cases. The operators would still have to observe the daily barometer and temperature, and make corrections, to the "local cubic foot." The only suggested advantage discernible is that the consumers everywhere throughout the region or State in question would get the same number of heat units in the yearly average "local cubic foot." What they get from day to day will vary by the same amounts under any system. All features considered, it will be much more satisfactory to fix the requirement in terms of the atmospheric standard cubic foot, *i. e.*, at 30 inches barometer and 60° F. The average "local cubic foot" sold will then contain slightly different numbers of heat units according to the height of the locality above the sea and to the climatic conditions. In New York State these differences are unimportant.

37. The conditions governing, the use of the standard are important. Gas manufacture is not an exact science but is a complex operation including a number of distinct processes. Quality of coal, methods of firing, temperature of retorts, the human factor, the failure or breakdown of parts of the plant, and other factors not easily controlled, make it impossible for a Gas Company to deliver an absolutely uniform

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product. This points to the necessity of applying the standard as an average for a reasonable length of time. A month has been adopted elsewhere and is recommended for New York State. If a Company falls below the standard for a few days it will then be necessary for it to produce above the standard, at an economic loss, in order to have its monthly average satisfactory. In order to protect the public against improper management by which there would be wide departures from the standard, should a minimum value be set? It is not necessary that this minimum be set too close to the monthly average, as there is a financial loss to a Company if it departs too far from it. The cheapest and best operation for both Company and consumer will obtain by a close adherence to the standard. A wide departure due to careless operating means an increase in operating cost which will not be to the Company's profit. A 5 per cent. deviation for not exceeding three consecutive days would be adequate protection to the consumer. In extraordinary conditions due to failure to obtain supplies or to accident in the plant, the Commission might properly suspend the operation of the standard in its discretion.

38. As a matter of fact even a properly fixed minimum is of little practical importance. Well-managed companies would never reach it except under circumstances absolutely beyond their control. The saving and satisfaction in operating close to the monthly average is very great and induces good management. A management continually inefficient and incompetent would be exposed in so many ways that a change would eventually come through reorganization or new ownership.

39. Penalties have been used in an attempt to compel good management, but as a rule, experience has shown them to be ineffective. The difficulties of placing the blame on the proper persons and conditions, of proper legal phrasing, of collecting the penalties, of fixing equitable penalties and penalties that are real, the fact that through carelessness they so frequently

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fall into disuse, the opportunity that exists for abuse and persecution—all operate against the effectiveness of a penalty system. Continual and broad publicity is very much better. The greatest force in the country to-day is public opinion. No company could ignore or withstand the effect of frequently published statements that its product was not up to a prescribed standard. A weekly publication of tests, for example, would keep the public informed, would keep the company active in good management, would prevent careless and irresponsible complaints, and would prevent abuse and criticism.

40. It is reasonable to ask what disadvantage there will be, if any, to persons using flat flame burners if a standard is fixed according to heating value only. It is fair to exclude from consideration all persons who continue to use flat flame burners through indifference to their own interests. That a smaller and smaller number of people are doing this is evident from the results reported by gas companies in regard to the reduction in the number of consumers using open flames. Mantle burners have become so cheap and the saving is so great that in a short time no one will use open flame burners except for some peculiar reason. The cases will be remarkably few where open flame burners will be thought desirable, but for those who feel that they must use them it may be stated positively that any artificial gas having the heating value recommended in the above standard would have sufficient illuminating power, though at times lower than at present, to make the gas useful in locations suitable to open flame burners. The use of a very small percentage of the gas for such a purpose should not prevail against the general usefulness of the whole product.

41. The Committee recommends, therefore, that no candlepower standards be considered in connection with the heat unit standard heretofore recommended.

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APPENDIX A

HISTORY OF COMMITTEE AND ITS WORK.

1. In August, 1908, an investigation was started by the Public Service Commission Second District, N. Y., through its Division of Light, Heat and Power "into the subject of the calorific power and illuminating power of the coal gas, carbureted water gas, and mixed coal and carbureted water gas supplied." (Page 21, Third Annual Report.)

2. This examination, as stated in the Third Annual Report of the Commission, was of a preliminary nature, and was completed in October, 1909, and the data embodied in a report by the Chief of Division of Light, Heat and Power.

3. On December 8, 1909, notice was sent by the Commission to all the gas companies operating in the Second Public Service District of a conference to be held on February 1, 1910, in reference to this subject.

4. In December, 1909, following the receipt of this notice and report, the Empire State Gas and Electric Association appointed a Committee to investigate the matter as thoroughly as might be done prior to the hearing of February first. This Committee held a number of meetings, discussed the matter contained in the report and such other data as was available, but was unable to arrive at any definite conclusion in the very limited time at its disposal.

5. At the hearing on February 1, 1910, after some general discussion, a vote was taken on the question as to whether or not the investigation started by the Commission should be continued. The result of the vote being in the affirmative, the Chairman of the Commission suggested the appointment by the representatives of the gas companies present, of a Committee to co-operate with the Commission's representatives This suggestion having met with the approval of all

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those present, a recess was declared, during which the companies held a meeting and elected as their representatives:

W. R. Addicks,
T. R. Beal,
J. C. DeLong,
W. T. Morris,
M. W. Offut,
R. M. Searle.

6. Upon the continuation of the conference the Chairman of the Commission named as its representatives:

H. C. Hazzard,
H. H. Crowell,
C. H. Stone.

The persons above named convened after adjournment of the hearing and voted to hold the first regular meeting in the Capitol, Albany, on Friday, February 11.

7. On February 11, 1910, the Committee appointed as above outlined, met and elected H. C. Hazzard, Chairman, and C. H. B. Chapin, Secretary. It was voted that the Committee should be known as the Joint Committee on Calorimetry.

8. Since its original appointment, the personnel of the Committee has undergone some changes. The Commission has appointed William McClellan and C. F. Leonard as its representatives, H. H. Crowell and C. H. Stone having severed their connection with it. H. H. Crowell continued to serve upon the committee, and C. H. Stone resigned, but by unanimous invitation continued to sit with the committee and was later re-elected a member. M. W. Offutt resigned as a member of the Committee and M. J. Brayton was elected in his place. Dr. A. H. Elliott and J. B. Klumpp were elected additional members of the Committee. H. C. Hazard having resigned from the service of the Commission, thereupon resigned from the Committee, and W. R. Addicks was elected Chairman.

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9. At the commencement of the investigation, the Committee deemed it desirable to secure the co-operation of Companies in different parts of the State and operating under different conditions of manufacture and distribution of gas. Ten Companies decided to purchase calorimeters and make such tests as the Committee desired. Before the conclusion of the investigation additional Companies joined in the work, so that the Committee had results from sixteen plants located in widely separated parts of the State to aid it in its conclusions.

10. Statistics are given in Table 1 showing the kind of gas made by these Companies, the magnitude of the daily output, and the date of beginning of tests. Companies are designated by number instead of by name throughout the report. (For further information regarding the different Companies see Appendix B.)

TABLE I.

Company No.	Class	Kind of gas	Tests started
1	A	Coal gas, enriched	Oct. 1, 1911
2	D	Coal gas, enriched	Aug. 1, 1911
3	A	Carbureted water gas	Aug. 1, 1911
4	A	Carbureted water gas	Aug. 1, 1911
5	C	Carbureted water gas	Aug. 1, 1911*
6	B	Carbureted water gas	Aug. 1, 1911
7	B	Carbureted water gas	Aug. 1, 1911
8	C	Carbureted water gas	Aug. 1, 1911
9	A	Carbureted water gas	Aug. 1, 1911
10	B	Carbureted water gas	Oct. 1, 1911
11	A	Mixed coal and carbureted water gas	Aug. 1, 1911
12	A	Mixed coal and carbureted water gas	Aug. 1, 1911
13	C	Mixed coal and carbureted water gas	Aug. 1, 1911
14	C	Mixed coal and carbureted water gas	Apr. 1, 1912
15	A	Carbureted water gas	Oct. 1, 1912
16	B	Carbureted water gas	Feb. 1, 1912

Class A—Companies having a maximum daily send-out of over 1,000,000 cubic feet.

Class B—Companies having a maximum daily send-out from 500,000 to 1,000,000 cubic feet.

* Tests discontinued November 30, 1911, and calorimeter moved to another plant.

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Class C—Companies having a maximum daily send-out from 100,000 to 500,000 cubic feet.

Class D—Companies having a maximum daily send-out of under 100,000 cubic feet.

11. At the meeting of the Committee in February, 1910, it was deemed advisable to prepare specifications for calorimeter installations and rules for their operation. This work, which was done by a sub-committee, was completed and adopted by the full Committee on May 6, 1910, and printed for distribution under the title "Calorimetric Rules, Regulations and Specifications." Copies were furnished to all Gas Companies operating in New York State.

This pamphlet is divided into six general sections as follows:

I. Heating Value of Gas (Definition).[1]
II. Primary Standard—To be maintained at the laboratory of Commission at Albany (Specifications).
III. Secondary Standard—To be used in checking Calorimeters of Gas Companies in situ (Specifications.)
IV. General Specifications and Recommendations for Calorimeter Installations by Gas Companies.
V. Directions for Operating Calorimeter.
VI. Suggestion of Several Types of Calorimeters Suitable to Use when Checked by the Primary Standard Adopted.

12. Following the adoption of these specifications, the Public Service Commission, Second District, purchased necessary instruments and equipped a laboratory where the instruments of the different Companies could be calibrated.

[1] The definition of the heating value of gas adopted by the Committee for the purposes of this report and the investigations conducted is as follows:

"The heating value of a gas is the total heating effect produced by the complete combustion of a unit volume of the gas, measured at a temperature of 60 degrees Fahrenheit, and a pressure of 30 inches of mercury, with air of the same temperature and pressure, the products of combustion also being brought to this temperature.

"In America the unit of volume is the cubic foot and we recommend that the heating value be stated in terms of British Thermal Units per cubic foot of gas."

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13. The delays in delivery of instruments were considerable, so that the calibration of the companies' calorimeters at the State laboratory was not completed until early in 1911. It was deemed wise by the Committee to allow a preliminary period after the instruments were finally installed for the companies' operators to become acquainted with the methods of testing before asking that the results be submitted to it for inspection.

14. During this preliminary period forms were prepared to be used by the companies in recording their daily readings and in submitting the results each month to the Committee.

15. Observations of the results obtained during the first few months of testing prompted the Committee to prepare a second pamphlet which was printed under the title "Plan of Calorimetric Investigation and Explanation of Test and Report Forms." A copy of this pamphlet was furnished each company engaged in the investigation. Amended forms for recording and reporting daily readings and works data were also prepared.

16. This second pamphlet, which was tentatively adopted January 6, 1912, treated in further detail the following subjects:

1. The making of daily calorimetric tests and the recording daily of certain works data.
2. The submitting to the Committee monthly the results of the daily tests and of monthly averages and details of works data.
3. The furnishing to the Committee of information regarding operating conditions, and apparatus and methods in use.

17. Beginning with August 1, 1911, and ending October 31, 1912, a period of fifteen months, reports have been regularly received by the Committee and each month tabulated by the Secretary so that copies could be in the hands of each member of the Committee for individual study. During this period 6,738 calorimetric tests and 9,167 photometric tests were reported as shown in Tables II and III respectively.

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TABLE II.—CALORIMETRIC TESTS.

Company	August, 1911	September	October	November	December	January, 1912	February	March	April	May	June	July	August	September	October	Total	
No. 1	—	—	25	25	22	6	1	7	26	25	25	16	26	23	25	252	
No. 2	31	30	31	30	25	25	24	25	25	26	23	22	25	23	22	387	
No. 3	24	23	26	25	25	27	25	25	—	25	26	25	27	24	27	354	
No. 4	29	28	29	28	31	29	32	26	28	32	29	24	24	17	14	400	
No. 5 ...	27	25	26	25	—	—	—	—	—	—	—	—	—	—	—	103	
No. 6	29	27	28	28	29	31	29	28	30	30	30	31	30	27	26	433	Works
No. 6	—	—	—	—	—	20	15	26	30	30	30	31	28	26	31	267	Outlying station
No. 7	27	30	31	27	26	26	26	26	26	27	25	26	25	21	7	376	
No. 8	27	25	27	24	24	27	23	26	26	26	25	26	25	26	26	383	Inst. A at works
No. 8	27	25	27	24	24	26	23	26	26	26	25	26	25	26	26	382	Inst. B at works
No. 8	27	25	27	24	24	24	23	26	26	26	25	26	25	26	26	380	Inst. C at office
No. 9	31	30	31	25	24	26	24	26	26	25	25	26	26	25	27	397	
No. 10	—	—	26	25	22	26	22	26	24	24	25	26	27	23	26	322	
No. 11	26	24	26	25	24	25	24	26	26	26	24	24	27	23	26	376	Coal gas
No. 11	26	24	26	25	24	26	24	26	26	26	24	24	27	22	26	376	Water gas
No. 11	26	24	26	25	24	26	25	26	26	25	25	24	27	23	26	378	Mixed gas
No. 12	26	20	26	25	21	20	21	21	19	12	18	26	19	19	21	314	
No. 13	26	25	26	25	25	24	25	26	26	26	25	26	27	15	27	374	
No. 14	—	—	—	—	—	—	—	—	28	31	30	31	31	30	29	210	
No. 15	—	—	—	—	—	—	—	—	—	—	—	—	—	23	27	50	Works
No. 15 ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	23	23	Outlying station
No. 16	—	—	—	—	—	—	19	26	26	13	13	27	27	24	26	201	
Total	409	385	464	435	394	414	405	444	470	481	472	487	498	466	514	6,738	

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TABLE III.—PHOTOMETRIC TESTS.

Company	August, 1911	September	October	November	December	January, 1912	February	March	April	May	June	July	August	September	October	Total	
No. 1	—	—	26	25	25	26	1	7	26	26	25	16	26	24	25	278	Works
No. 3	31	30	31	30	30	31	29	25	—	25	25	26	31	30	31	406	Works
No. 3	27	25	26	24	25	26	24	26	—	25	23	26	26	23	27	351	Office
No. 4	31	30	30	30	31	31	32	29	29	32	29	24	24	17	15	414	Works
No. 5	27	25	26	25	—	—	—	—	—	—	—	—	—	—	—	103	Meter shop
No. 6	31	30	31	30	31	31	29	31	30	31	30	31	31	30	31	458	Works
No. 6	—	—	—	—	—	31	29	31	30	31	30	31	31	30	31	305	Outlying station
No. 7	27	30	31	28	26	24	26	28	27	27	25	26	24	22	25	396	Works
No. 7	23	22	26	25	25	26	25	24	26	26	22	24	26	24	26	370	Office
No. 8	27	25	27	24	24	27	23	26	26	26	25	26	25	26	26	383	Works
No. 8	27	25	27	24	24	27	23	26	26	26	25	26	25	26	26	383	Works
No. 8 ...	27	25	27	24	24	27	23	26	26	26	25	26	25	26	26	383	Office
No. 8	27	25	27	24	24	27	23	26	26	26	25	26	25	26	26	383	Office
No. 9	31	30	31	30	31	31	29	31	30	31	30	31	31	29	31	457	Works
No. 9	31	30	31	27	24	27	25	26	26	25	25	26	26	26	27	402	Office
No. 9	31	30	31	27	24	27	25	26	26	25	25	26	26	26	27	402	Office
No. 10	—	—	26	25	24	26	23	25	24	25	25	25	27	23	26	324	Office
No. 11	27	25	26	25	25	24	24	25	26	25	24	24	27	23	26	376	Coal gas
No. 11	27	25	26	25	25	26	24	25	26	26	24	24	27	22	26	378	Water gas
No. 11	27	30	26	25	25	31	25	26	26	26	25	24	27	23	26	392	Mixed gas
No. 12	31	30	31	30	31	31	29	31	30	31	30	26	19	19	21	420	Works
No. 12	26	23	26	25	25	20	22	26	26	26	25	—	—	—	—	270	Office
No. 13	26	25	26	25	25	26	25	26	26	26	25	26	27	24	27	385	Office
No. 14	—	—	—	—	—	—	—	—	30	30	30	31	31	30	31	213	Works
No. 14	—	—	—	—	—	—	—	—	29	31	30	31	31	30	29	211	Office
No. 15 ...	—	—	—	—	—	—	—	—	—	—	—	—	—	25	27	50	Works
No. 15	—	—	—	—	—	—	—	—	—	—	—	—	—	25	23	48	Outlying station
No. 16	—	—	—	—	—	—	19	26	26	26	25	27	27	24	26	226	Meter shop
Total	562	538	615	577	548	603	557	598	623	680	653	629	645	651	688	9,167	

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18. In May, 1912, a meeting of the Committee was held at Amsterdam which was attended by the men operating the calorimeters in the several plants. At this time a general conference was held and a discussion of the work, with particular reference to uniformity and accuracy, took place.

19. Sub-committees have taken up in detail matters that were considered of enough importance to require special study. Frequent meetings of the Committee have been held during the past two years and the work constantly reviewed with an endeavor to consider every phase of the question. An analysis of the work, the results of the tests and the conclusions drawn therefrom, will be found elsewhere in the report.

INTRODUCTORY OBSERVATIONS RELATING TO THE STUDY OF APPENDIX B.

1. Laboratory accuracy cannot be applied in commercial gas production. The engineer cannot predict from day to day the quality of gas that will be produced, not only because of the uncertainties in the character of the raw material, but also because of climatic conditions. It will be observed therefore that, owing chiefly to atmospheric changes, an excess candle-power exceeding 10 per cent. at the plants is frequently not realized at official testing station, even though the minimum realized meets the State candle-power requirements. This necessary condition tends to the serving of an irregular product which the charts clearly disclose.

2. Similarly, when operating under a heat unit standard. the engineer must continue to make his product in excess of the standard adopted. The information derived from the test indicates that the consumer will receive a much more uniform and satisfactory product which should work for greater efficiency in its use at the point of consumption when compared with operating under the candle-power standard where, even with uniform pressure, the essential readjustment of air supply is neglected; this is wasteful in use of gas and through carbonization (a too familiar sight with over-enriched gas)

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is destructive of gas mantles. This condition would be eliminated under the proposed heat unit standard and the present economic losses and annoyance in the use of gas due to this neglect in readjustment of air supply will be eliminated.

3. The adoption of the proposed standard will be a conservation of resources through the elimination of unnecessary wastes in production and distribution without loss in effectiveness of the product when compared with all elements of waste resulting from pursuing present methods.

4. It should be noted that a percentage variation from a standard of, for example, 5 per cent. is but 1 unit in the case of 20 as used in candle-power, while the same accuracy when dealing with the larger heat unit figure becomes 29 units (nearly) when dealing with heat unit standards, yet both 1 and 29 are figures that show equal percentage accuracy.

5. It should be kept in mind that a difference in reading by two observers of the same gas might reasonably be even 0.5 of a candle or nearly 3 per cent. in candle-power. It is probable that the variation in B. t. u. observation by the same observers would be less than 1 per cent. The following table may be found useful. It shows, for example, that a 5 per cent. variation from 20 candle-power is 1 or 21 candle-power; for 18 candle-power is 0.9 or 18.9 candle-power; from 16 candle-power is 0.8 or 16.8; while from 570 B. t. u. it is 28.50 or 599 (nearly).

TABLE SHOWING RESULTANT ILLUMINATING OR HEATING VALUE FOR VARIATIONS IN THE QUALITY OF THE GAS, ABOVE STANDARD, OF FROM 1 TO 13 PER CENT.

Standard	1 per cent.	2 per cent.	3 per cent.	4 per cent.	5 per cent.	6 per cent.
20 Candle-power	20.2	20.4	20.6	20.8	21.0	21.2
18 Candle-power	18.2	18.4	18.5	18.7	18.9	19.1
16 Candle-power	16.2	16.3	16.5	16.6	16.8	17.0
570 B. t. u.	576.0	581.0	587.0	593.0	599.0	604.0

Standard	7 per cent.	8 per cent.	9 per cent.	10 per cent.	11 per cent.	12 per cent.	13 per cent.
20 Candle-power	21.4	21.6	21.8	22.0	22.2	22.4	22.6
18 Candle-power	19.3	19.4	19.6	19.8	20.0	20.2	20.3
16 Candle-power	17.1	17.3	17.4	17.6	17.8	17.9	18.1
570 B. t. u.	610.0	616.0	621.0	627.0	633.0	638.0	644.0

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APPENDIX B

1. As already noted in Appendix A, pages 555 and 556, there have been 6,738 calorimetric tests and 9,167 photometric tests reported to the Committee during the period August 1, 1911, to October 31, 1912. It has seemed unnecessary to include all of these tests in detail in this report, but the monthly averages are given in Table IV. These averages are in all cases based on the actual number of tests made during the month. The table also gives the minimum monthly average of heating value for each Company and the average illuminating value for the month during which the minimum average heating value ocurred.

2. The results of the tests throughout the entire period are shown graphically in the following pages. Data in regard to the works and operation of the various Companies are also given.

3. The charts were prepared to show the variations in the quality of gas, both daily and from month to month. There are separate diagrams for the heating value and the illuminating value.

4. The zero line represents the average for a complete year, except when tests did not cover so long a period. In each case the actual figure represented by the zero line is given, and the months included in the average are stated. The average for each month is shown by a heavy line indicating the percentage of variation above or below the yearly average. The cross-sectioning represents the extreme high and low variation of any daily readings during such month in percentage of the monthly average.

5. The illuminating values and their variations from the yearly and monthly average are shown according to the same method in the second diagram.

6. A careful study of these diagrams indicates that the percentages of variation in heating values from day to day

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TABLE IV.—CARBURETED WATER GAS.
Standard Candle-power Required at Testing Station 20.

Month	Company No. 3 At works Average		Company No. 4 At works Average		Company No. 5 At meter shop Average		Company No. 6				Company No. 7 At works Average	
							At works Average		Testing station Average			
	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.
August, 1911	621	22.8	642	23.3	624	20.7	613	23.8	—	—	605	20.7
September	631	22.5	644	23.7	616	21.1	613	24.9	—	—	615	20.7
October	636	22.9	632	22.5	635	20.6	612	23.4	—	—	617	20.5
November	657	22.5	635	22.1	634	19.6	615	22.9	—	—	623	21.1
December	661	22.4	627	21.9	—	—	637	23.1	—	—	625	22.6
January, 1912	669	21.8	622	20.5	—	—	631	22.8	619	19.9	635	25.1
February	650	23.1	645	22.0	—	—	634	23.2	618	20.4	631	25.6
March	643	24.1	631	22.4	—	—	624	22.8	620	20.4	630	25.6
April	—	—	626	22.1	—	—	627	23.3	617	20.2	628	25.5
May	628	23.3	634	23.5	—	—	638	23.2	621	20.5	621	22.5
June	622	22.1	630	22.7	—	—	643	23.2	636	20.7	610	21.7
July	622	21.3	644	22.4	—	—	646	23.1	639	21.1	607	21.1
August	619	20.6	643	22.3	—	—	636	23.1	631	20.7	613	21.5
September	624	21.3	644	22.5	—	—	630	22.9	616	20.2	619	21.5
October	630	20.7	652	22.3	—	—	638	23.4	626	20.4	629	21.6
Min. Avg. B. t. u. and C. P. same month	619	20.6	622	20.5	616	21.1	612	23.4	616	20.2	605	20.7

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TABLE IV.—CARBURETED WATER GAS—(*Continued*).

Month	Company No. 8 At works Average		Company No. 8 At office Average		Company No. 9 Testing station Average		Company No. 10 At office Average		Company No. 15 At works Average		Company No. 15 Outlying station Average		Company No. 16 At meter shop Average	
	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.
Augnst. 1911	617	19.1	613	20.0	589	20.8	—	—	—	—	—	—	—	—
September	610	18.9	605	19.6	597	20.6	—	—	—	—	—	—	—	—
October	594	18.7	584	19.3	619	21.2	625	21.2	—	—	—	—	—	—
November	633	19.7	622	19.9	625	20.4	632	21.2	—	—	—	—	—	—
December	645	22.5	642	20.9	638	20.7	626	20.7	—	—	—	—	—	—
January, 1912	653	22.4	643	21.1	631	20.9	626	20.5	—	—	—	—	—	—
February	650	22.6	631	20.6	621	20.7	634	20.6	—	—	—	—	625	20.5
March	621	20.3	607	19.8	610	20.7	618	20.4	—	—	—	—	619	20.8
April	602	18.7	591	20.4	600	20.2	620	20.6	—	—	—	—	620	20.6
May	592	19.5	590	19.9	589	20.6	629	20.9	—	—	—	—	621	21.2
June	592	19.3	596	20.7	595	20.6	624	21.2	—	—	—	—	631	21.0
July	584	17.9	586	20.6	597	20.6	619	21.2	—	—	—	—	639	20.7
August	592	19.3	591	20.1	588	20.5	633	21.9	—	—	—	—	626	21.2
September	607	19.7	605	21.0	592	20.2	615	20.8	627	20.9	—	—	626	20.7
October	615	20.4	618	20.5	597	20.6	605	20.4	629	22.2	606	17.6	622	21.1
Min. Avg. B. t. u. and C. P. same month	584	17.9	584	19.3	588	20.5	605	20.4	627	20.9	606	17.6	619	20.8

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TABLE VI.—CARBURETED WATER GAS—(*Continued*).

Month	Mixed coal and carbureted water gas*								Coal gas—Enriched				Coal gas Unenriched	
	Company No. 11 At works Average		Company No. 12 At works Average		Company No. 13 At office Average		Company No. 14 At office Average		Company No. 1 At works Average		Company No. 2 At office Average		Company No. 11 At works Average	
	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.	B. t. u.	C. P.
August, 1911	626	20.0	590	21.3	611	18.2	—	—	—	—	660	Not reported	602	14.9
September	640	20.4	592	21.3	623	18.3	—	—	—	—	654		616	15.3
October	628	20.6	596	21.5	661	18.7	—	—	683	18.7	654		611	13.5
November	643	20.9	611	21.9	624	18.6	—	—	674	18.0	651		607	13.8
December	649	20.5	615	21.9	633	18.4	—	—	667	17.7	647		621	14.2
January, 1912	672	20.5	635	21.6	632	18.5	—	—	653	17.5	630		628	13.7
February	656	21.4	645	21.5	641	18.4	—	—	—	—	636		614	13.7
March	646	20.4	647	21.1	626	18.3	—	—	626	16.5	616		612	14.9
April	636	20.8	647	20.9	626	18.6	605	18.6	641	16.4	637		612	13.5
May	628	21.5	642	20.8	633	18.4	634	19.4	656	16.9	651		601	14.7
June	624	19.7	631	20.6	620	18.4	623	18.5	642	16.6	662		610	15.3
July	610	19.9	617	20.3	635	18.6	618	18.6	638	17.0	646		593	14.3
August	614	19.7	628	20.4	627	18.4	618	18.9	645	16.8	644		591	13.7
September	612	19.8	622	20.5	621	18.4	611	18.7	653	17.0	646		595	14.2
October	623	20.4	633	20.5	625	18.5	603	18.4	650	17.8	618		592	13.1
Min. Ave. B. t. u. and C. P. same month	610	19.9	590	21.3	611	18.2	603	18.4	626	16.5	616		591	13.7

* In connection with table, note that the present standard for mixed coal and carbureted water gas is 18 candle-power and for enriched coal gas 16 candle-power.

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and from month to month are considerably less than the percentages of variation in illuminating values, that the variations in monthly averages for the two measures of quality do not parallel one another and that there is no definite relation between them.

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COMPANY. NO. I

Works.—Kind of coal—¾ screened Pennsylvania gas coal. Class A—Table I. Page 552. Duration of charge—4 hours.

Operation.—Coal gas plant with water gas auxiliary, not in use daily. One holder housed, six exposed. Yield per pound coal—4.79 to 4.94 cubic feet (cor.)

Tests.—Tests made at works. Coal gas enriched with oil gas. Type of calorimeter—Junkers—American Meter Co. Temperature of atmosphere not reported each month, probable range during period of tests from 0° to 100° F.

Curves.—Zero lines represent average heating power or illuminating power for period October 1, 1911, to September 30, 1912, excepting February, 1912, for which month no tests were reported. Average heating power = 652 B. t. u. Average illuminating power = 17.2 candle-power.

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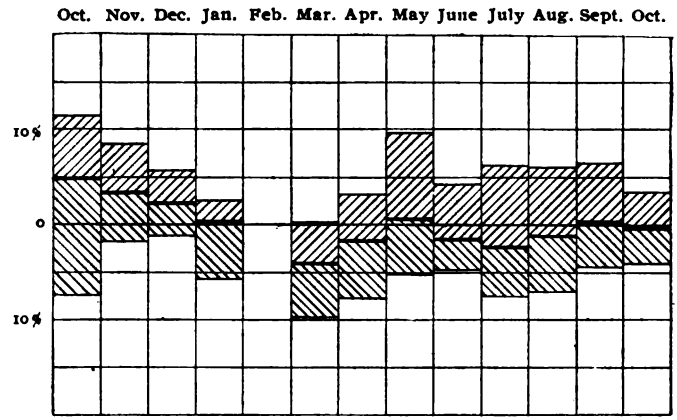
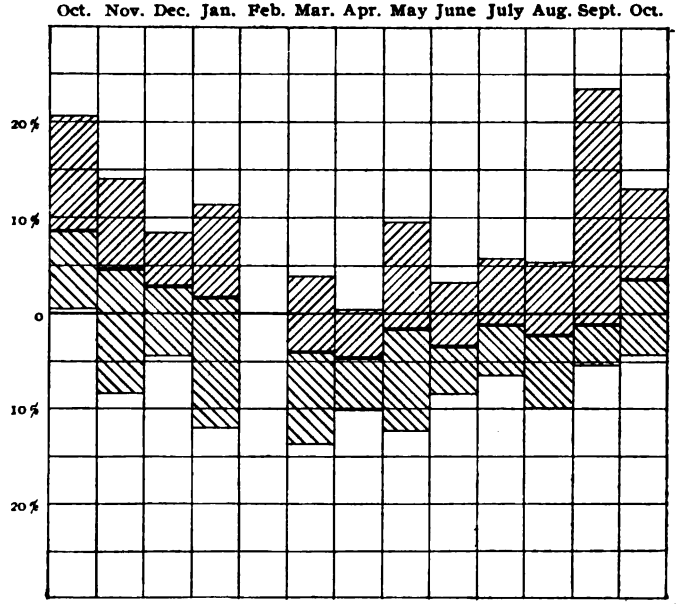
VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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COMPANY NO. 2

Works.—Coal gas plant. Class D—Table 1. Page 552. Holders exposed. Horizontal retorts. One-half depth furnace.

Operation.—Enricher—cannel—coal—8.57 to 9.23 pounds per 100 pounds coal carbonized. Kind of coal—Pennsylvania. Duration of charge—from 5 hours 35 minutes to 7 hours 26 minutes. Yield per pound coal—December to July—4.78 to 5.25 cubic feet (cor.).

Tests.—Tests made at office. Type of calorimeter—Junkers. No photometric tests reported. Temperature of atmosphere ranged from—10° to 102° F.

Curves.—Zero line represents average heating power for 12 months—August 1, 1911, to July 31, 1912. Average heating power = 645 B. t. u.

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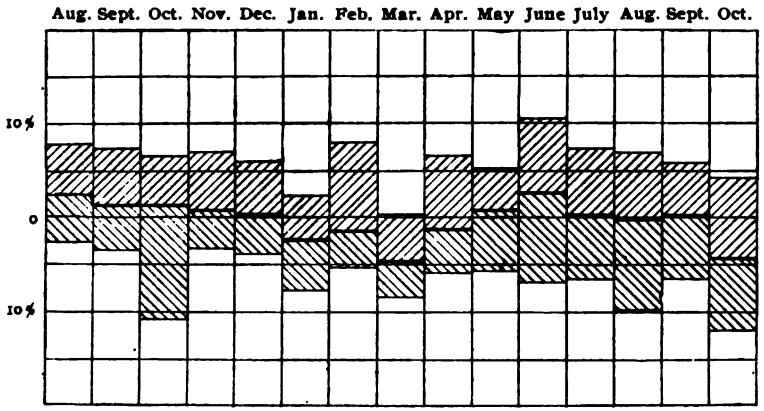
VARIATIONS IN HEATING POWER



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COMPANY NO. 3

Works.—Carbureted water gas plant. Class A—Table I. Page 552. Holders exposed. Generators—7′ 6″ and 12′ sets.

Operation.—Enricher—34° to 35° B. gas oil—3.68 to 4.48 gallons per thousand (cor.) Kind of fuel—Anthracite grate coal. Generator fuel per thousand (cor.)—31.55 to 37.44 pounds. Hours per day works operation—from 10 to 24.

Tests.—Tests made at works. Type of calorimeter—Junkers. Temperature of atmosphere ranged from—16° to 98° F.

Curves.—Zero lines represent average heating power or illuminating power for period August 1, 1911, to July 31, 1912, excepting April 1912, for which month no tests were reported. Average heating power = 640 B. t. u. Average illuminating power = 22.6 candle-power.

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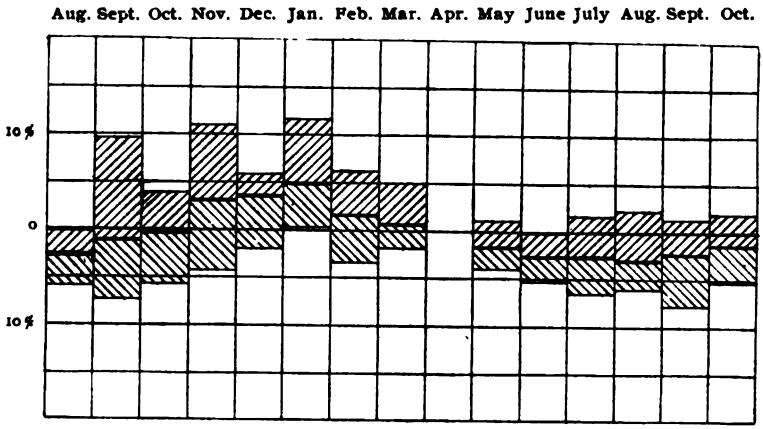
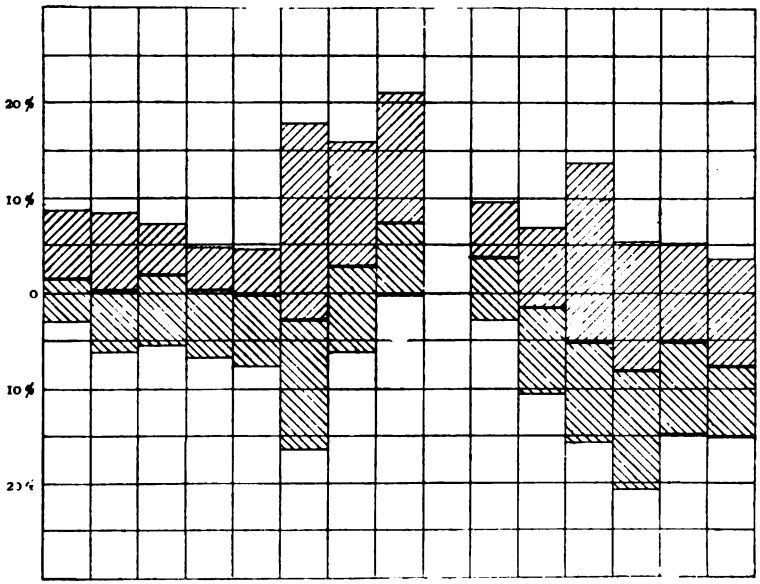
VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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COMPANY NO 4.

Works.—Carbureted water gas plant. Class A—Table I. Page 552. Holders exposed. Generators—U. G. I. Improved Lowe—up and down steam, 7′ 6″ and 8′ 6″ sets. Air and steam meters.

Operation.—Enricher—Gas—oil—3.80 to 4.19 gallons per thousand (cor.) Kind of fuel—Broken anthracite. Generator fuel per 1,000 (cor.)—29.7 to 35.7 pounds. Hours per day works operation from 4.5 to 23.8.

Tests.—Tests are made at works laboratory. Samples of gas taken from outlet of street main governor. Gas has been exposed to atmospheric temperature in storage holder and relief holder. Type of calorimeter—Junkers' 1910-American Meter Co. type of Photometer—U. G. I. 60-inch Bar. Edgerton Standard. No. 7 Bray burner. Temperature of atmosphere ranged from—4° to 97° F.

Curves.—Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912. Average heating power = 634 B. t. u. Average illuminating power = 22.4 candle-power.

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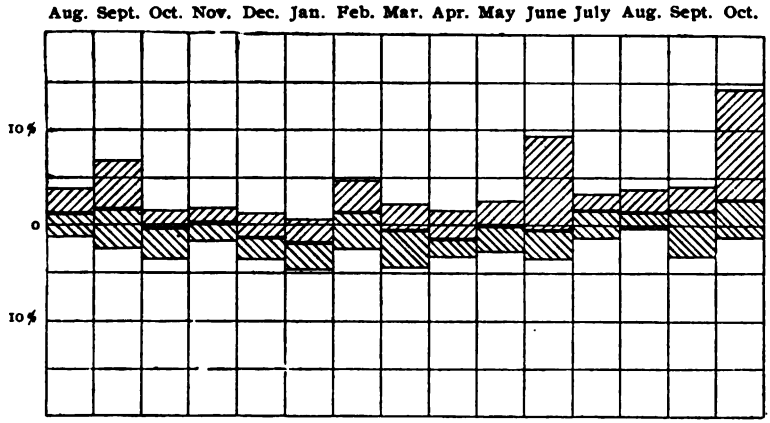
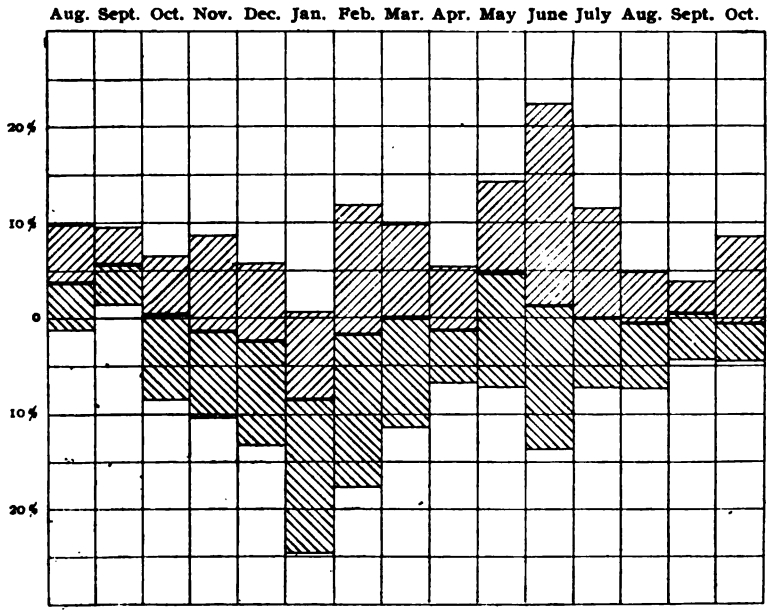
VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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COMPANY NO. 5

Works.—Carbureted water gas plant. Class C—Table I. Page 552. Relief holder housed.

Tests.—Tests made at a test station one-half mile from works. Type of calorimeter—Sargent. Temperature of atmosphere ranged from 27° to 97° F. during period of tests. NOTE.—This calorimeter was moved during December and January to plant of Company No. 16.

Curves.—Zero lines represent average heating power or illuminating power for four months—August 1, 1911, to November 30, 1911. Average heating power = 627 B. t. u. Average illuminating power = 20.5 candle-power.

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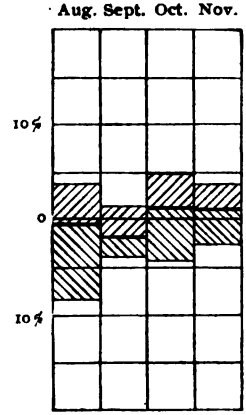
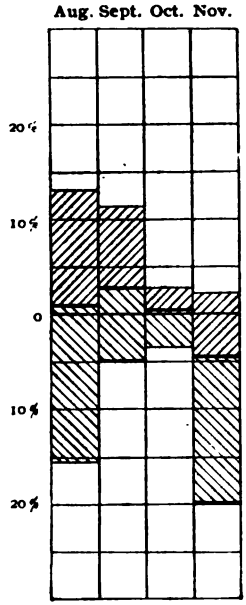
VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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COMPANY NO. 6

Works.—Carbureted water gas plant. Class B—Table I. Page 552. Holders—1 housed, 1 exposed, Works A; 1 exposed, Station B. Generators—U. G. I. Standard—up and down steam, 6′ sets.

Operation.—Enricher—Gas oil—3.59 to 4.11 gallons per thousand (cor.) Kind of fuel—Anthracite grate. Generator fuel per thousand (cor.)—27.31 to 30.48 pounds. Hours per day works operation from 9.18 to 22.45. Tests are made at works (A).

Tests.—Tests are also made at outlying station (B). See next page. Samples of gas, works A, taken at outlet of station governor. Type of calorimeter—Junkers. Type of photometer—U. G. I. Standard 60-inch Bar. Edgerton Standard checked by Pentane lamp. No. 7 lava tip burner. Temperature of atmosphere ranged from — 20° to 108° F.

Curves.—Zero lines represent the average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912. Average heating power = 628 B. t. u. Average illuminating power = 23.3 candle-power.

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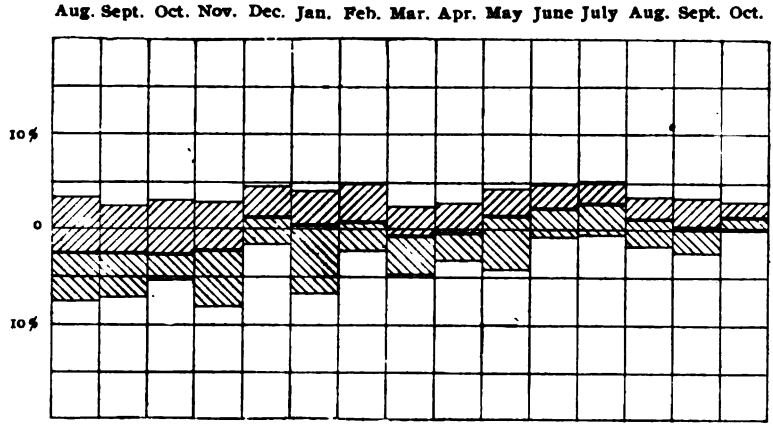
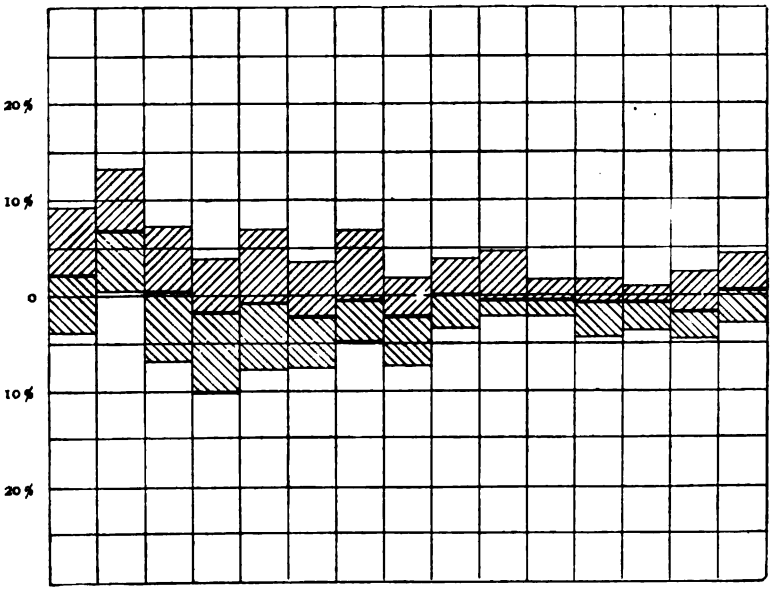
TESTS AT WORKS

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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COMPANY NO. 6.—(*Continued*)

Tests.—Works and operating data given on preceeding page. Tests made at outlying testing station (B). Samples of gas taken from inlet side of the governor on the outlet of exposed storage holder. For course of gas from works see map on page 613. Type of calorimeter—Junkers—American Meter Co. Type of photometer—U. G. I. Standard 60" bar. Pentane lamp—standard. No. 7 lava tip burner.

Curves.—Zero lines represent average heating power or illuminating power for 10 months—January 1 to October 31, 1912. Average heating power = 624 B. t. u. Average illuminating power = 20.5 candle-power. For further information see Appendix C, page 614.

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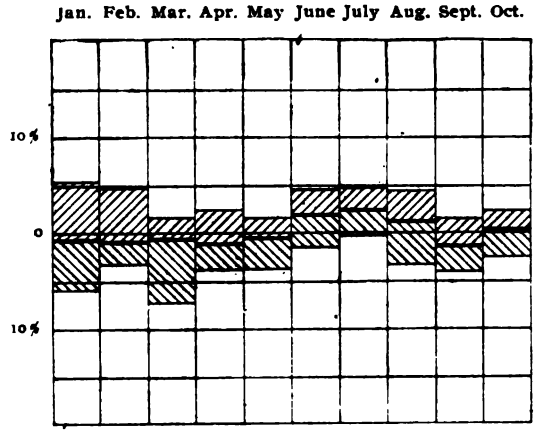
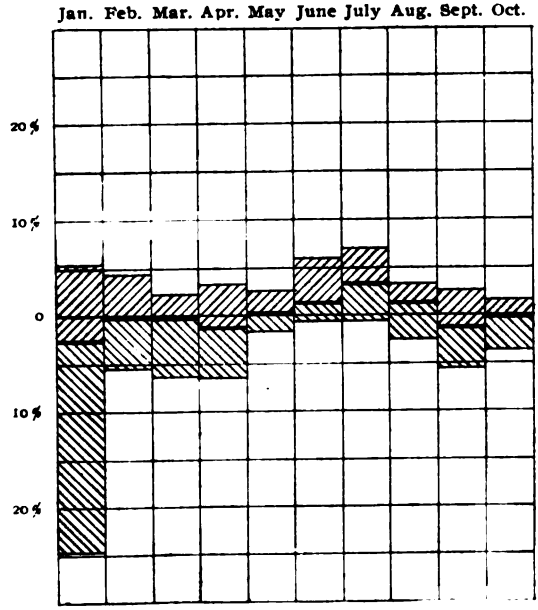
TESTS AT OUTLYING STATION

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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COMPANY NO. 7.

Works.—Carbureted water gas plant. Class B—Table I. Page 552. Holders exposed. Generators—Western Gas Const. Co., 7′ 6″ sets.

Operation.—Enricher—34° B. gas oil—3.06 to 3.84 gallons per thousand (cor.) Kind of fuel—Anthracite coal. Generator fuel per thousand (cor.)—31.7 to 35.4 pounds. Hours per day works operation from 7.5 to 20.7.

Tests.—Tests are made at works. Samples of gas taken from outlet of station governor. Gas has been exposed to atmospheric temperature in city holder. Type of calorimeter—Junkers. Type of photometer—Suggs-Letherby open type. Standard—Hefner lamp burning imported Amylacetate. Burner—Argand F. Temperature of atmosphere ranged from —20° to 95° F.

Curves.—Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912. Average heating power = 621 B. t. u. Average illuminating power = 22.7 candle-power.

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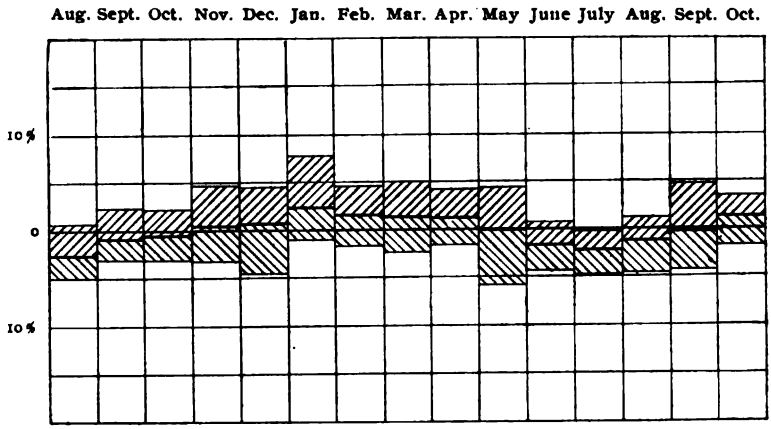
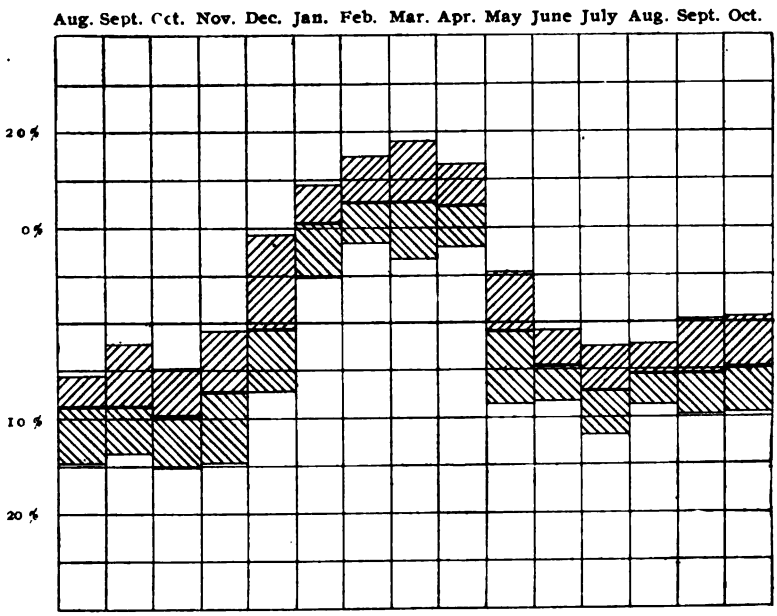
VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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COMPANY NO. 8.

Works.—Carbureted water gas plant. Class C—Table I. Page 552. Holders exposed. Generators—5′ and 7′ 6″ sets. Pyrometers on sets.

Operation.—Enricher—28° B. oil—3.5 to 4.65 gallons per thousand (cor.) Kind of fuel—Broken anthracite and from 80 to 89 per cent. anthracite remainder gas house coke during March, April, May and June. Generator fuel per thousand (cor.)—35.90 to 40.8 pounds. Hours per day works operation from 8 to 23.8.

Tests.—Tests are made at works (A) and also made at testing station (B). See page 582. Samples of gas at works (A) taken from distribution main governor inlet. Type of calorimeter—Junkers and Sargent. (Although results of tests with Sargent calorimeter were reported, they have not been used in connection with accompanying curves to avoid duplicating curves unnecessarily.) Type of photometer—60″ Open Bar. U. G. I. Standard—Genuine English Spermaceti candles weighing 6 to the pound Burner—No. 7 L. P. Slit Union Bray and "New F" Argand Sugg pattern. Temperature of atmosphere ranged from—3° to 100° F.

Curves.—Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912. Average heating power* = 616 B. t. u. Average illuminating power = 20 candle-power.

N. B.—Average heating power Sargent same period, 616 B. t. u.

* See also Appendix C, page 624.

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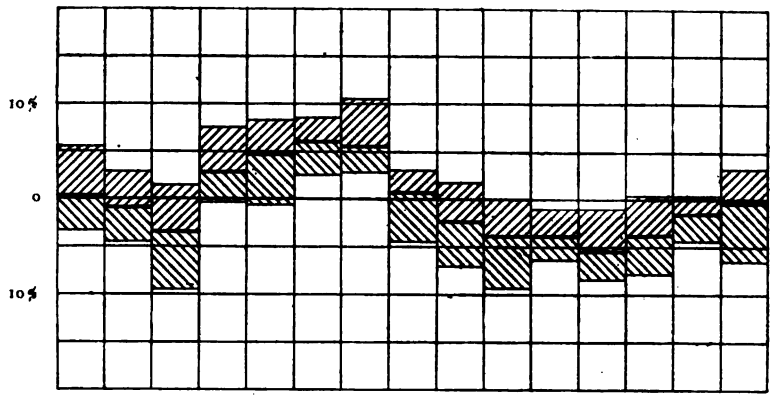
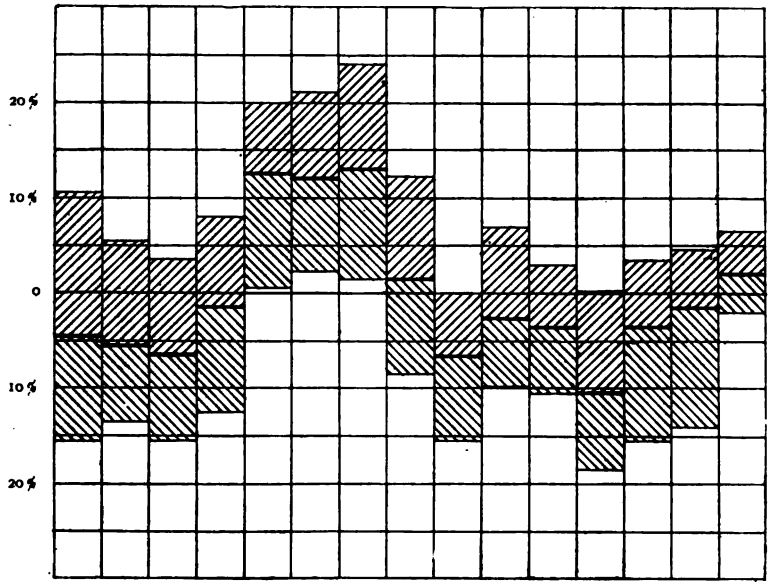
TESTS AT WORKS

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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COMPANY NO. 8.—(*Continued*)

Works and operating data given on page 580.

Tests.—Tests made at testing station (B). Samples of gas are taken direct from service entering building from street main. Type of calorimeter—Junkers. Type of photometer —60″ open Bar. American Meter Co. Standard—Genuine English Spermaceti candles weighing 6 to the pound. Burner—No. 7 L. P. Slit Union Bray and "New F" Argand Sugg pattern.

Curves.—Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912. Average heating power = 609 B. t. u. Average illuminating power = 20.2 candle-power.

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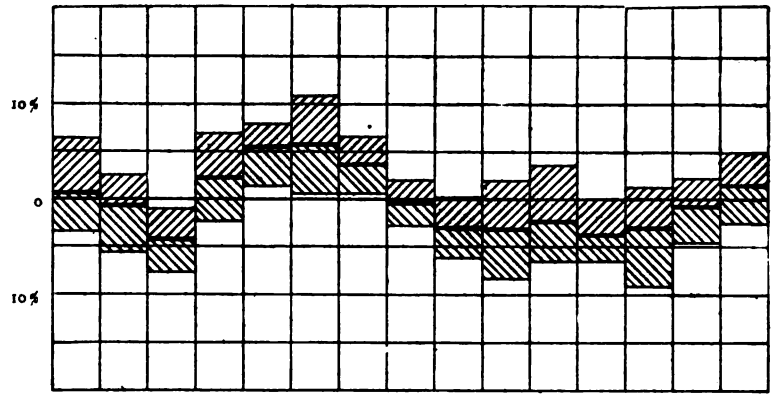
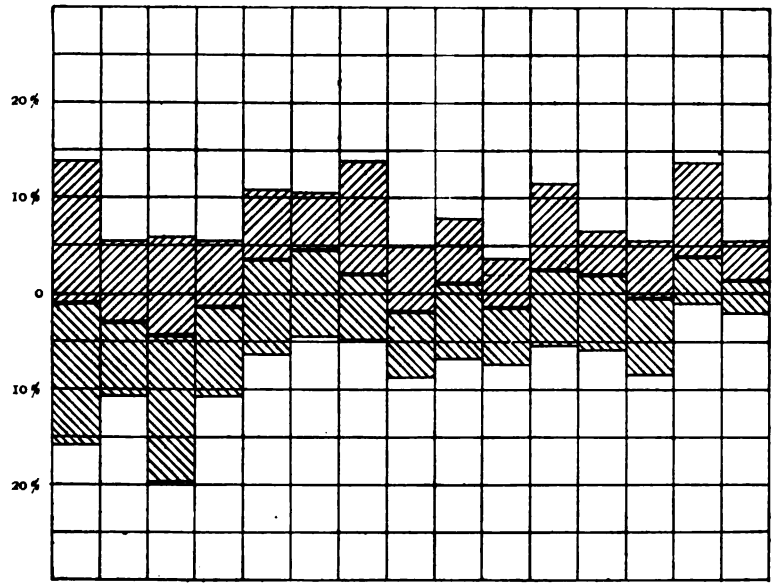
TESTS AT TESTING STATION

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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COMPANY NO. 9.

Works.—Carbureted water gas plant. Class A—Table I. Page 552. Holders exposed. Generators—11′ x 16′ 7″ and 12′ x 16′ 7″ Lowe reverse steam sets. Indicating and Recording Pyrometers.

Operation.—Enricher—28° B. gas oil—3.41 to 4.34 gallons per thousand (cor.) Kind of fuel—Anthracite. Generator fuel per thousand (cor.)—30.45 to 32.67 pounds. Hours per day works operation—continuous running.

Tests.—Tests are made at testing station exceeding 1 mile from works. Samples of gas taken directly from service entering building from the street main. Gas has been exposed to atmospheric temperature in holders and ground temperatures in mains. Type of calorimeter—Junkers. Type of photometer—60″ open Bar, American Meter Co. Standard—Genuine English Spermaceti candles weighing 6 to the pound. Burners—No. 7 L. P. Slit Union Bray and "New F" Argand Sugg pattern. Temperature of atmosphere ranged from—2° to 98° F.

Curves.—Zero lines represent the average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912. Average heating power = 609 B. t. u. Average illuminating power—20.7 candle-power.

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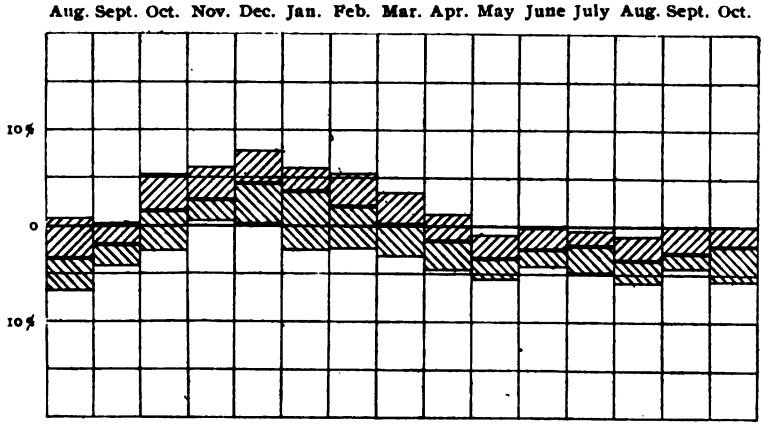
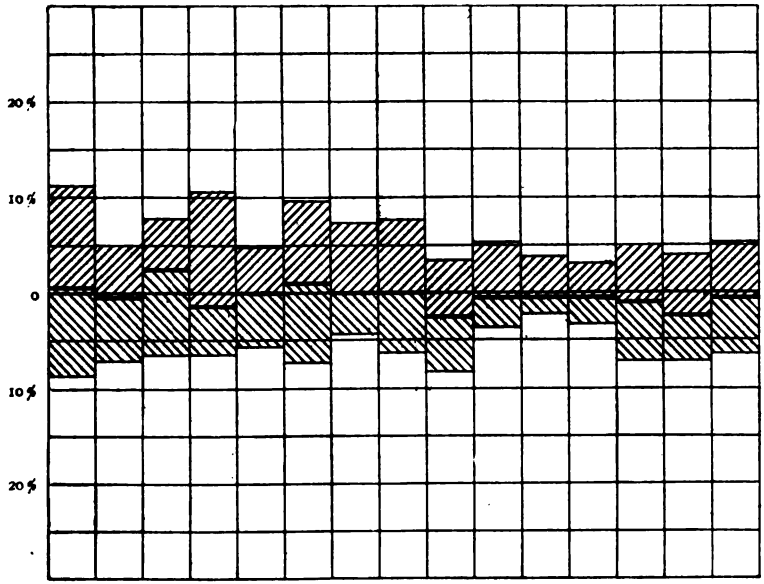
VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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COMPANY NO. 10.

Works.—Carbureted water gas plant. Class B—Table I. Page 552. Storage holder exposed. Relief holder housed. Generators—5′ Western Gas Const. Co. sets, one with no down-run valve, one with down-run valve.

Operation.—Enricher—28° to 34° B. gas oil—3.91 to 4.47 gallons per thousand (cor.) Kind of fuel—Anthracite grate. Generator fuel per thousand (cor.)—38.3 to 46.9 pounds. Hours per day works operation—3 1/7 to 15½.

Tests.—Tests are made about ¼ mile from works. Samples of gas taken direct from regular service into the building. Gas has been exposed to atmospheric temperatures in holder and to ground temperature in mains. Type of calorimeter—Sargent. Type of photometer—80″ closed Bar. American Meter Co. Standard—Candles. Burner—Either "New F" Argand or No. 7 Slit Union Bray. Temperature of atmosphere not reported.

Curves.—Zero lines represent the average heating power or illuminating power for 12 months—October 1, 1911, to September 30, 1912. Average heating power = 626 B. t. u. Average illuminating power = 21 candle-power.

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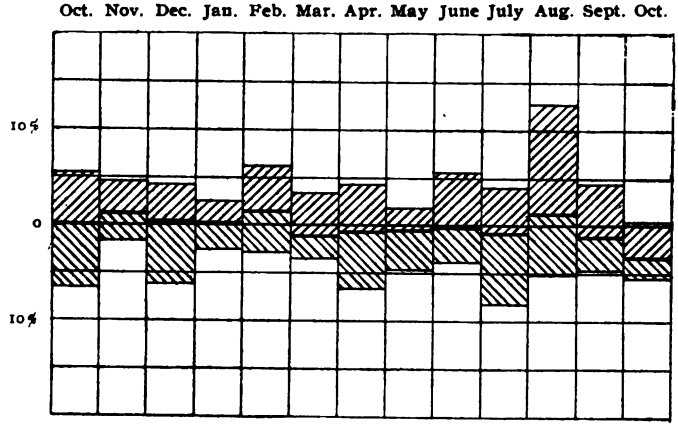
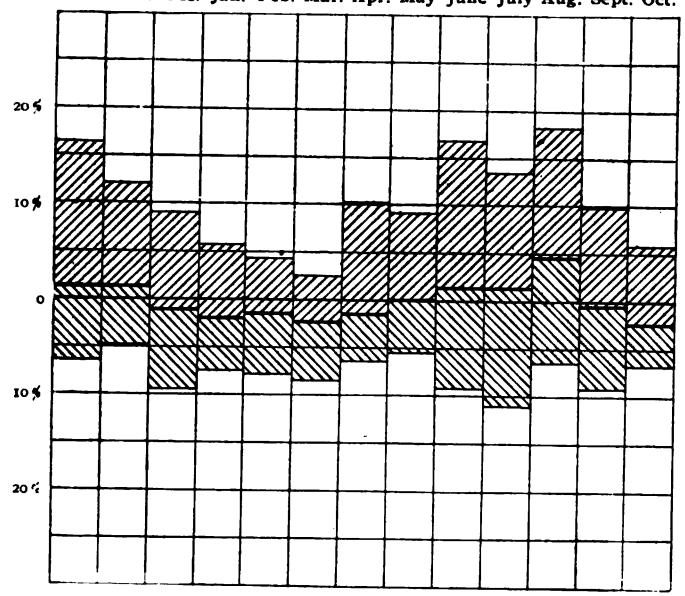
VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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COMPANY NO. II.

Works.—Mixed coal and carbureted water gas plant. Class A—Table I. Page 552. Holders exposed. Generators 8′ 6″, 10′ 0″, 10′ 0″ Twin Gen., U. G. I. sets. Benches—10 Parker-Russell 9s.

Operation.—Water gas—Enricher—35° to 37° B. gas oil—3.77 to 4.48 gallons per thousand (cor.) Kind of fuel—Anthracite coal, retort coke and oven coke. Generator fuel per thousand (cor.)—32.27 to 36.19 pounds. Hours per day works operation—continuous running. Coal gas—Kind of coal—Pennsylvania gas coal. Yield per pound coal cor. gas—4.71 to 4.96 cubic feet. Duration of charge—4 hours. Mixed gas—Mixture from 16.4 per cent. coal gas and 83.6 per cent. water gas to 24.7 per cent. coal gas and 75.3 per cent. water gas.

Tests.—Tests are made at works. Tests were made of the carbureted water gas, of the coal gas and also of the mixed gas. Type of calorimeter—Junkers—American Meter Co. Type of photometer—not reported. Burner—No. 7 Bray Slit Union. Temperature of atmosphere ranged from—4° to 94° F.

Curves.—The curves given below are for the mixed-coal and carbureted water gas. (Curves for straight coal gas are on page 590). Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912. Average heating power = 638 B. t. u. Average illuminating power = 20.6 candle-power.

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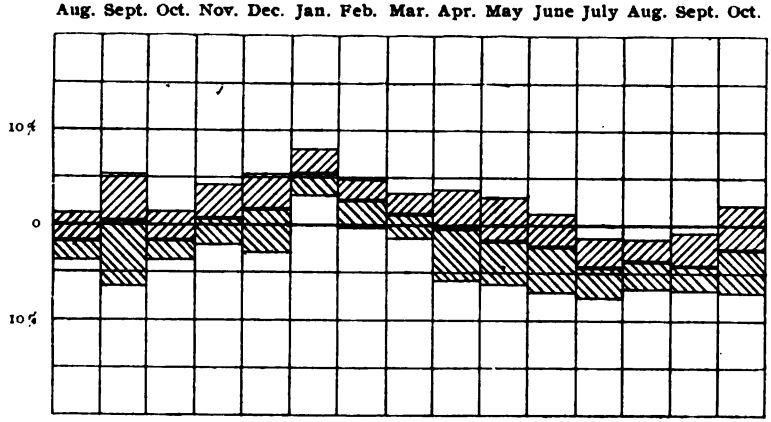
VARIATIONS IN HEATING POWER



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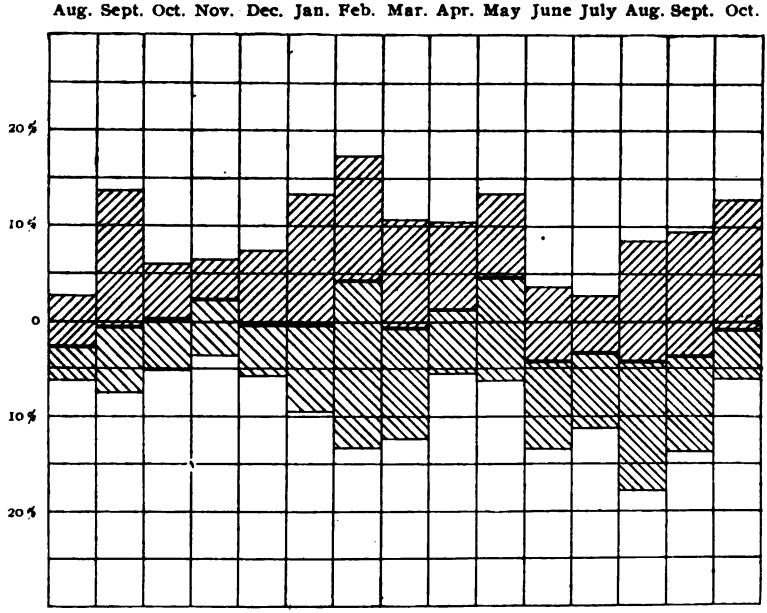

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COMPANY NO. 11.—(*Continued*)

Unenriched coal gas.

Data regarding works, operation and tests are given on page 588.

Curves.—Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912. Average heating power = 611 B. t. u. Average illuminating power = 14.3 candle-power.

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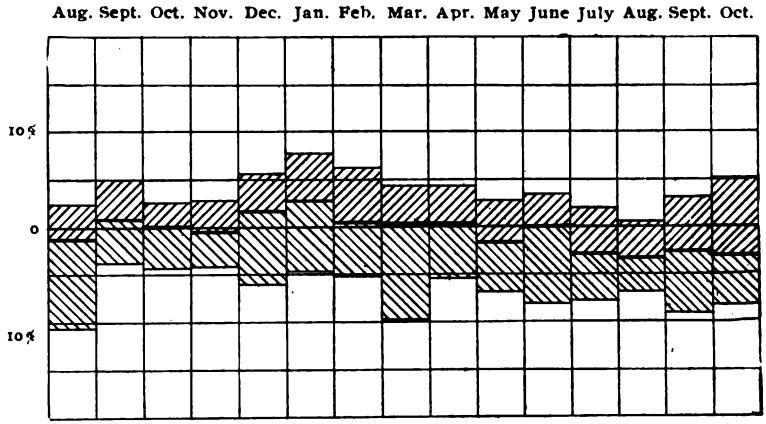
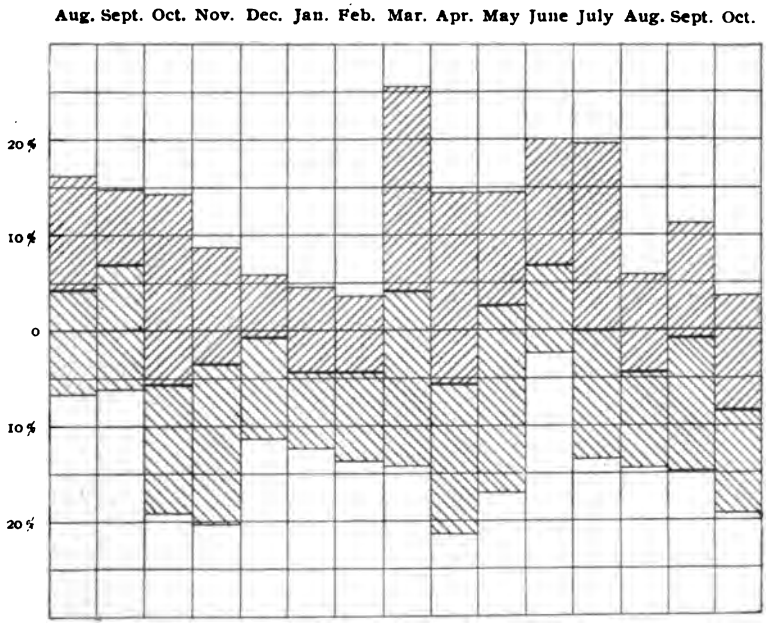
UNENRICHED COAL GAS

VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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COMPANY NO. 12.

Works.—Mixed coal and carbureted water gas plant. Class A—Table I. Page 552. One holder exposed, others housed. Generators—7′ 6″ H. & G. and 8′ 6″ U. G. I. Benches—½ depth horizontal.

Operation.—Water gas—Enricher—35° B. gas oil—3.52 to 4.33 gallons per thousand (cor.) Kind of fuel—Retort house coke. Generator fuel per thousand (cor.)—27.96 to 33.45 pounds. Hours per day works operation—continuous running. Coal gas—Kind of coal—Pennsylvania gas coal. Yield per pound coal (cor.) gas—4.55 to 5.22 cubic feet. Duration of charge—4 hours. Mixed gas—Mixture from 19.21 per cent. coal gas and 80.79 per cent. water gas to 26.8 per cent. coal gas and 73.2 per cent. water gas.

Tests.—Tests are made at works. Samples of gas taken at inlet to works governor. Type of calorimeter—Junkers. Type of photometer—60″ Standard U. G. I. Bar Standard—Edgerton standard checked daily by Pentane lamp Burner—7′ lava tip burner. Temperature of atmosphere ranged from—8° 116° F.

Curves.—Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912. Average heating power = 622 B. t. u. Average illuminating power = 21.2 candle-power.

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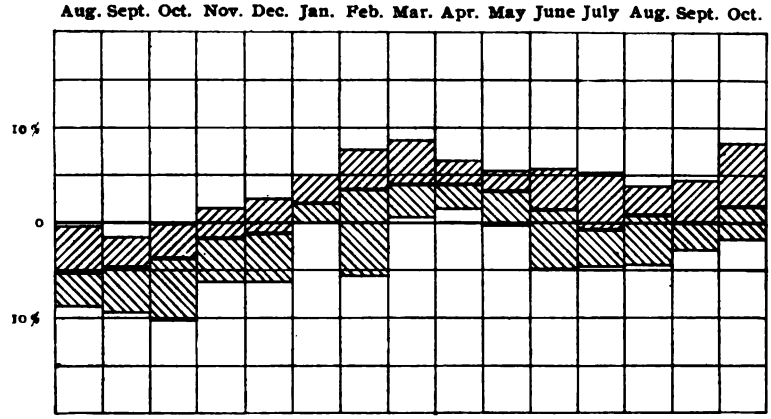
VARIATIONS IN HEATING POWER



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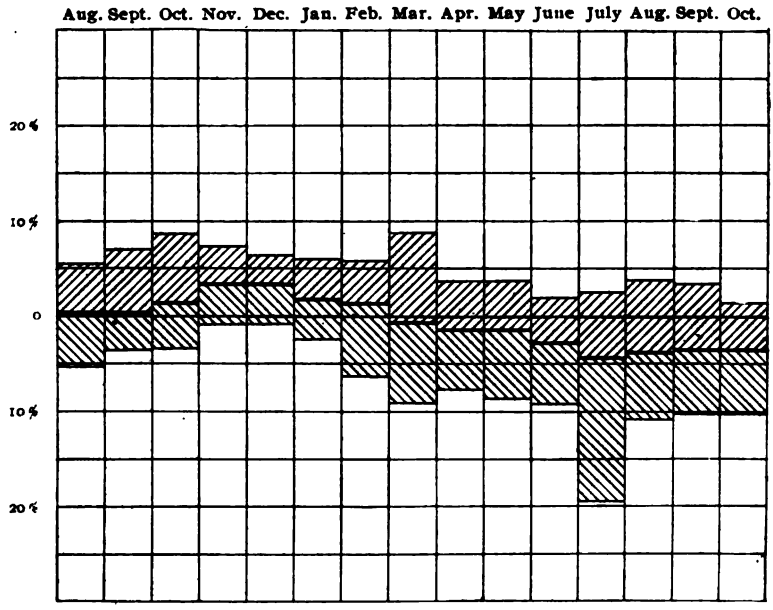

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COMPANY NO. 13.

Works.—Mixed coal and carbureted water gas plant. Class C.—Table I. Page 552. Holders housed. Generator—6 feet Lowe set.

Operation.—Water gas—Enricher—gas oil—3.4 to 4.3 gallons per thousand (cor.) Kind of fuel—Coke. Generator fuel per thousand (cor.)—41.09 to 48 pounds. Hours per day works operation from 2 hours 43 minutes to 12 hours 45 minutes. Coal gas—Kind of coal. Pennsylvania yield per pound coal (cor.)—4.75 to 5.5 cubic feet. Duration of charge—from 4 hours to 6 hours 20 minutes. Mixed gas—Mixture from 53 per cent. coal gas and 47 per cent. water gas to 68 per cent. coal gas and 32 per cent. water gas.

Tests.—Tests are made at office. Type of calorimeter—Junkers. Temperature of atmosphere not reported regularly —from—10° to probable 100° F.

Curves.—Zero lines represent average heating power or illuminating power for 12 months—August 1, 1911, to July 31, 1912. Average heating power = 630 B. t. u. Average illuminating power = 18.5 candle-power.

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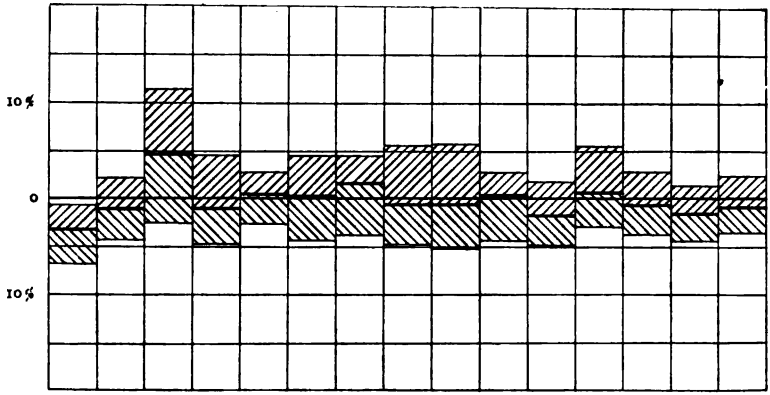
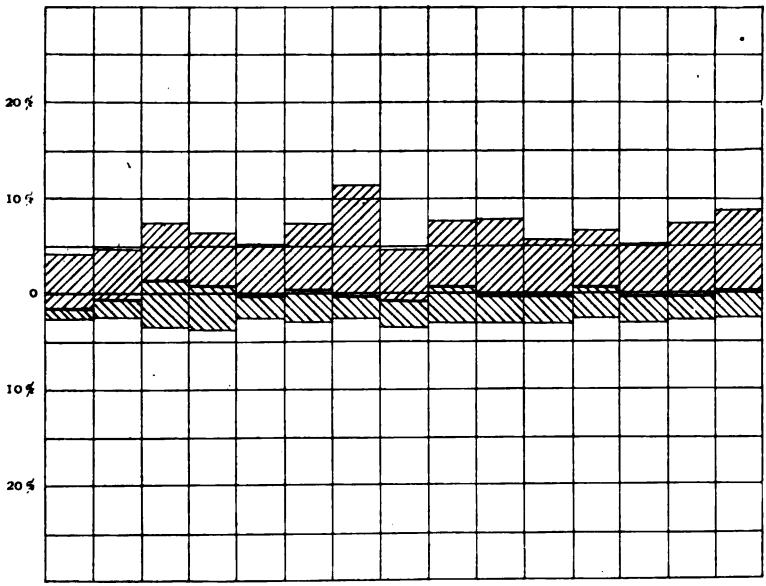
VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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COMPANY NO. 14.

Works.—Mixed coal and carbureted water gas plant. Class Class C—Table I. Page 552. Holders—at works, exposed. Outlying, housed. Generators—5′ double superheater, Lowe set. U. G. I. pattern with down-run connections. Benches—½ depth benches of 6s by Improved Equipment Co.

Operation.—Water gas—Enricher—gas oil—3.93 to 4.63 gallons per thousand (cor.) Kind of fuel—Gas coke. Generator fuel per thousand (cor.)—34.37 to 39.28 pounds. Hours per day works operation from 5 hours 38 minutes to 17 hours 15 minutes. Coal gas—Kind of coal—Pennsylvania. Yield per pound coal (cor.)—4.29 to 4.96 cubic feet. Duration of charge—4 hours. Mixed gas—Mixture from 31.18 per cent. coal gas and 68.82 per cent. water gas to 54 per cent. coal gas and 46 per cent. water gas.

Tests.—Tests made at office 3½ miles from works. Samples of gas taken from regular distribution main through service entering building. Type of calorimeter—Junkers—American Meter Co. Type of photometer—60′ open Bar. U. G. I. Standard—Double candles. Burner—Sugg F or occasionally Sugg D or Bray special. Temperature of atmosphere ranged from 22° to 84° F.

Curves.—Zero lines represent average heating power or illuminating power for 7 months—April 1 to October 31, 1912. Average heating power = 616 B. t. u. Average illuminating power—18.7 candle-power.

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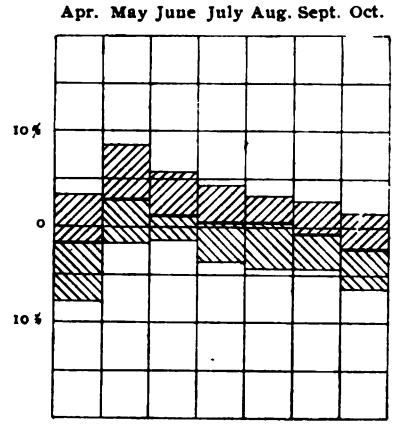
VARIATIONS IN HEATING POWER



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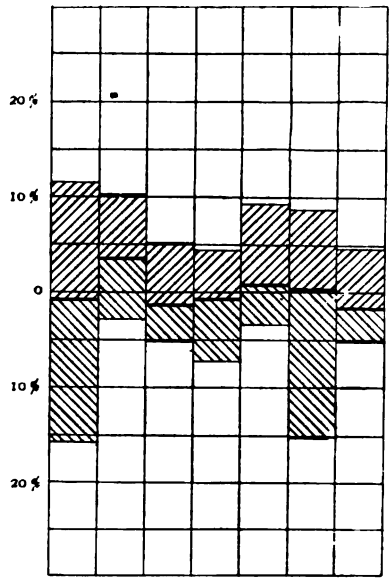

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COMPANY NO. 15.

Water.—Carbureted water gas plant. Class A—Table I. Page 552. Holders exposed. Generators—9′ and 12′ Williamson.

Operation.—Enricher—34.1° B. gas oil. Kind of fuel—Anthracite coal and coke. Hours per day works operation—12 to 18 hours. For information regarding transmission, see map, page 616, and explanation of tests, pages 555 and 556. Tests not having been started until September 1, 1912, no diagram has been made of the results.

COMPANY NO. 16.

Works.—Carbureted water gas plant. Class B—Table I. Page 552. Holders exposed.

Operation.—Enricher—Gas oil—3.60 to 4.21 gallons per thousand (cor.) Kind of fuel—Anthracite. Generator fuel per thousand (cor.)—33.82 to 41 pounds. Hours per day works operation from 6.24 to 14.4.

Tests.—Tests are made at testing station, 1½ miles from works. Type of calorimeter—Sargent. Temperature of atmosphere ranged from 2° to 102° F.

Curves.—Zero lines represent average heating power or illuminating power for 9 months—February 1 to October 31, 1912. Average heating power = 625 B. t. u. Average illuminating power = 20.9 candle-power.

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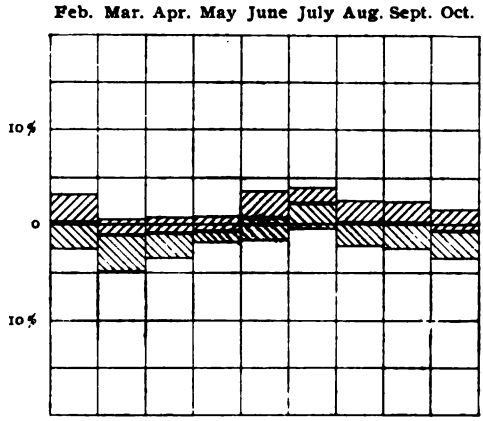
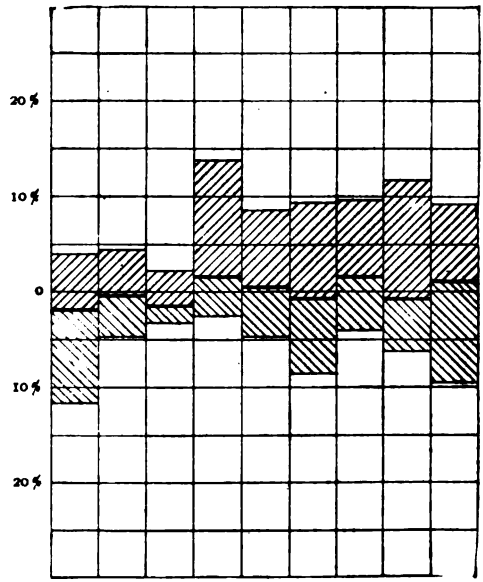
VARIATIONS IN HEATING POWER



VARIATIONS IN ILLUMINATING POWER



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7. The accompanying diagram has been prepared for the purpose of demonstrating the fallacy of the impression which still exists in some quarters that there is a definite relation between the illuminating power and the heating power of the gas. The results of all tests, made at the works, of coal gas, carbureted water gas, and mixed coal and carbureted water gas, have been considered in the preparation of this diagram with the exception of tests of unenriched coal gas. Tests showing a heating power below 575 or above 650 have also been excluded, as they were exceptional and as they were doubtless due to some extraordinary conditions.

8. With the exceptions noted, all of the results obtained during the fifteen months covered by the tests when plotted fall within the shaded portion of the diagram. In other words, gas having a heating power of 575 B. t. u. has been shown to have an illuminating power anywhere between the limits of 16.6 and 21.4 candle-power. Similarly, gas of 620 B. t. u. is shown to have an illuminating power anywhere between the limits of 16.8 and 25.6 candle-power.

9. It might have been expected that the limits would be fairly wide apart in all cases, but that the tendency of the shaded portion of the diagram would follow a direction corresponding to higher candle-power for higher heating values. Possibly if all of the tests were plotted and the values weighted a tendency of this character would be noted. It is, however, a fact that the minimum candle-power, reported at any time 14.9 candle-power, was found when the gas had a heating power of 590 B. t. u. and that the next lowest candle-power, 15.1 candle-power, was found when the gas had a heating power of 638 B. t. u. Similarly, the highest candle-power reported, 26.8 candle-power, occurred when the gas had a heating power of 634 B. t. u.; the next highest candle-power, 26.6 candle-power, occurred when the gas had a heating power of 629 and 632; the third highest candle-power, 26.5 candle-power occurred on five occasions, the gas having heating power of 603, 627, 633, 634 and 639.

(See Diagram on page 601.)

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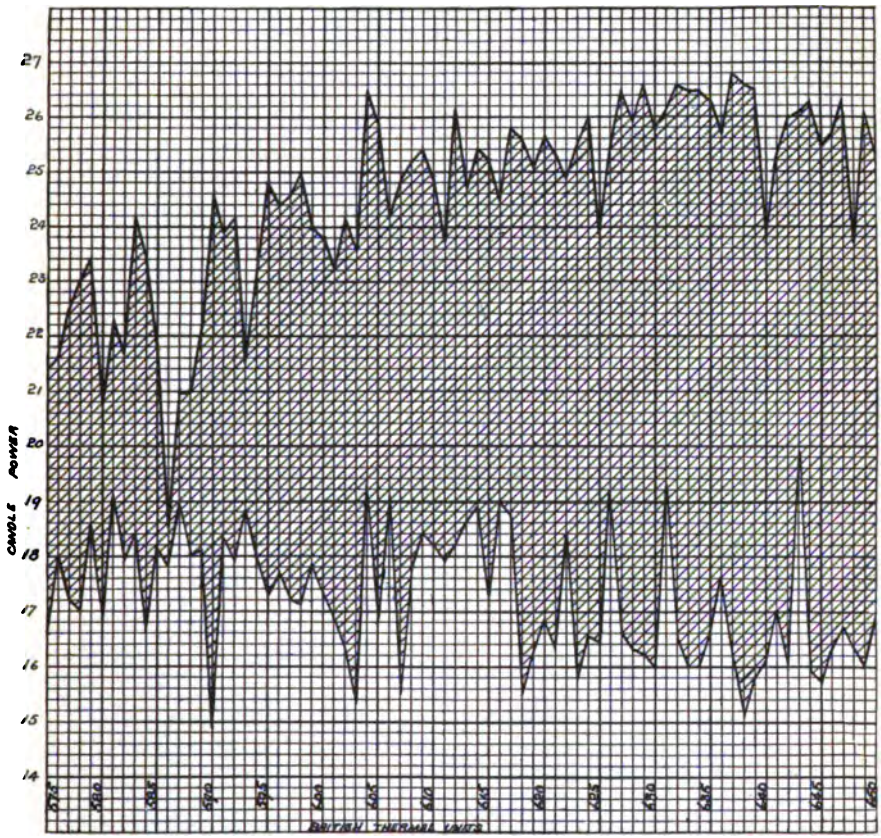

Range in candle-power, at works, of gas having heating values of from 575 to 650 B. t. u.

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APPENDIX C

MANUFACTURE AND DISTRIBUTION WITH REFERENCE TO ILLUMINATING VALUE AND HEATING VALUE

UNENRICHED COAL GAS

1. Only one Company (No. 11) participating in the investigation reported the illuminating value and heating value of straight unenriched coal gas. From the reports submitted it has been found that the average illuminating value of this coal gas, for a full year, as read at the manufacturing plant, is 14.3 candle-power, with a maximum individual daily reading of 18.1 and a minimum of 11.4—on a No. 7 Bray special burner. This gas is reported to be made from the best gas coal obtainable, and generated under good average conditions in horizontal retorts, with yields of only 4.71 to 496 cubic feet.

2. The present State requirements demand at the testing station a 16 candle-power coal gas. It will be seen that under these requirements, the manufacture and sale of straight coal gas, without enrichment, is not permissable. To meet the requirements a coal gas must be enriched the greater part of the year with either gas made from cannel coal or gas made from oil.

3. Should a coal gas be enriched by mixing with a carbureted water gas, the gas would then be classified as a mixed gas and the present requirements would demand 18 candle-power. To obtain this result would mean a large percentage of a high candle-power water gas—from 22 to 25 candle-power—to bring the mixture up to the required quality, an increasingly difficult process with the deterioration in the quality of oil obtainable.

4. The enrichment of coal gas with a gas made from cannel coal is not generally practiced. The coke made from this coal is of little value as a by-product, and if mixed with the coke obtained from gas coal, reduces the value of the entire product, thus increasing the cost of manufacture without compensating

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results in the quality of gas thus obtained. The supply of a good grade of cannel coal is limited, and if generally used, it is doubtful whether an adequate supply could be obtained. This method of enrichment is used only under peculiar and unusual conditions.

5. Enrichment with heavy oil by generating oil gas in coal gas retorts has been considered generally inefficient and expensive; and light oils are no longer available. It is a practice that, where possible, has been abandoned by nearly all coal gas companies; but some method of enrichment is compulsory under the present requirements of this State.

6. Benzol enrichment, so-called, consists of adding light oil vapors in the shape of benzol and toluol to the gas in the form of a spray, to increase its illuminating value. This increase is only effective under certain favorable conditions and is lost, to some extent, when the gas is further subjected to low temperatures or high pressures. (See pages 608 and 609, paragraphs 25, 26 and 27.)

7. In enriching coal gas by making a mixed gas, the present standards demand an illuminating value two candles higher than required for coal gas. This method of manufacture was employed by Companies 11, 12, 13 and 14, but only one of these Companies (11) reported the illuminating value and heating value of the two gases separately, and it will be seen from the following table, which is a summary of its results, that a corresponding increase in the heating value was not obtained in the effort to bring the illuminating value of the mixed gas up to the required standard. It is seen that while the illuminating value of the coal gas is increased about 45 per cent., the heating value is only increased 5 per cent. It should also be noted that the coal gas is mixed with three to four times its own volume of carbureted water gas of high illuminating value.

	Coal gas	Carbureted water gas	Mixed gas
Illuminating value...	14.3 C-p.	22.5 C-p.	20.6 C-p.
Calorific value	609 B. t. u.	647 B. t. u.	639 B. t. u.

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8. The results of the entire fifteen months' readings by this Company, as reported to the Committee, on the illuminating value and the heating value of the straight coal gas, are shown below.

9. This gas was made from Pennsylvania gas coal in stop end retorts and is straight coal gas without enrichment; the illuminating value being determined on a No. 7 Bray special burner. The minimum day's reading for each month and the average for the month, are shown, as well as the average for the entire fifteen months. (See also Appendix B, pages 34 and 35.)

COMPANY NO. 11.

STRAIGHT UNENRICHED COAL GAS.

	Candle-power		B. t. u.	
Month	Minimum	Average	Minimum	Average
August, 1911	13.3	14.9	546	602
September	13.3	15.3	587	616
October	11.7	13.5	584	611
November	11.5	13.8	586	607
December	12.7	14.2	573	621
January, 1912	12.4	13.7	580	628
February	12.4	13.7	579	614
March	12.2	14.9	550	612
April	11.4	13.5	578	612
May	12.6	14.7	570	601
June	13.9	15.3	561	610
July	12.5	14.3	565	593
August	12.3	13.7	569	591
September	12.2	14.2	557	595
October	11.7	13.1	562	592
Minimum		13.1		591

10. The following figures (Par. 11) show the result from a coal gas plant—not participating in the investigation—using coal with a volatile constituent of 36 per cent., by weight, and producing a straight unenriched coal gas.

11. The generators and settings are designed to give a

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maximum yield of gas per pound of coal. The retorts are set horizontally and machine stoked. All results are corrected as to temperature and pressure. The burner is the new Sugg F, Argand. The heat unit averages are the result of ten calorimetric tests per month. A year's results are as follows:

Month	Average heating value of gas B. t. u.	Average illuminating value of gas candle-power	Yield per pound coal cubic feet
January	556.1	14.54	5.36
February	567.3	14.79	5.17
March	573.7	14.79	5.26
April	568.3	14.32	5.21
May	594.2	14.82	5.25
June	600.5	14.74	5.24
July	600.9	14.16	5.19
August	602.3	14.32	5.28
September	596.6	14.34	5.21
October	599.6	14.30	5.19
November	589.1	14.14	5.20
December	583.0	14.64	5.17
Minimum	556.1	14.14	5.17

12. For the purpose of confirming the above results, we submit the average candle-power of straight unenriched coal gas manufactured by two large gas plants, for each month covering a period of two years.

13. These values, which are the averages of hourly readings, are indicative of the illuminating value that may be obtained in an efficiently managed plant, using the best West Virginia gas coal, in horizontal retorts. Candle-power readings were made each hour of the twenty-four, on a No. 7 flat flame burner against a pentane lamp. Candle-power variations are due largely to changes from freshly mined coal to stored coal. Yield slightly in excess of 5 feet per pound.

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	Plant No. 1 Candle-power		Plant No. 2 Candle-power	
	1910	1911	1910	1911
January	12.61	11.44	12.65	11.97
February	12.40	12.20	13.34	13.28
March	12.03	13.01	13.50	12.63
April	12.69	12.46	12.91	12.11
May	11.65	13.00	12.03	13.08
June	11.96	12.68	11.84	13.22
July	11.44	13.11	11.40	13.11
August	11.25	12.20	12.07	11.82
September	11.39	13.30	12.27	13.10
October	11.11	13.62	13.38	12.83
November	12.60	13.34	11.96	12.37
December	12.59	12.80	12.54	13.99
Average	11.97	12.76	12.49	12.79

RECENT DEVELOPMENTS IN COAL GAS MANUFACTURE

14. Recent developments in connection with the manufacture of coal gas have appeared in the form of vertical gas retorts and chamber ovens. Among the features of these types of installation have been improvements in the methods of handling materials and by-products. The character of construction of these retorts has permitted the adoption of devices for charging coal and discharging coke that have eliminated much of the heavy work of stoking labor, which is particularly arduous during the hot summer months.

15. The installation of these types of retorts has been of benefit in the saving of ground space occupied and in some instances in overcoming the ventilation retort house problems during the time of charging and discharging.

16. Gasifying coal in bulk in relatively large units has allowed a longer time for carbonization of the charge, and has been somewhat effectual in increasing the total yield of gas from an equal quantity of coal, with, however, a slight reduction in the heating value and illuminating value per thousand.

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17. Lengthening the carbonizing time has been helpful in increasing the total heat in resultant gas, per ton of coal carbonized, thereby producing a general economic saving.

18. Developments along this line are showing rapid improvements at the present time and it seems advisable that the quality requirements of a gas should be so placed as to allow the adoption and use of these more recent methods in the manufacture of coal gas throughout this State.

COKE OVEN GAS

19. During the past decade a large number of coke oven plants have been erected throughout the United States. Many of these plants were installed in connection with industrial undertakings, requiring coke for their operation, and where they have been compelled to seek a market for the by-product gas.

20. In many instances the coals used by these coke ovens were selected for their ability to produce a good metallurgical coke and often these ovens were not operated to handle by-product gas most efficiently. But in later years the methods of operating coke ovens have been somewhat modified, with the result that the quality of the gas has been much improved. With a selection of coals better suited for gas-making purposes, a better quality of gas may be expected from the coke ovens. But where these ovens are operated for the purpose of producing a high-grade furnace coke, and not primarily for the production of gas, the so-called best gas coals cannot be used to the best advantage, and, therefore, we probably will not see the highest quality of coal gas made in coke oven plants.

21. A number of instances have already arisen where such by-product coke oven gas could have been utilized to advantage. The heating value approached that of unenriched retort coal gas, and could have been made to equal it by enrichment, or mixture with carbureted water gas. The illuminating value, however, could not be brought up to the

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present requirements, except by enriching costs that were commercially prohibitive, or by using too large a percentage of carbureted water gas, and therefore the supply could not be availed of. To permit the utilization of this gas by proper standards would prevent this useless waste, and would constitute a great economic saving.

22. It seems probable that such situations will occur more frequently in the future than in the past and it would appear to be good public policy to permit the use of such gas for general distribution.

23. Coke oven gas has been used by many gas companies in other States, in whole or in part, for distribution to general consumers.

24. The treatment of this gas, in a number of instances, by manufacturing companies, however, is quite different from that of ordinary coal gas produced by gas companies, in that the operators of the coke ovens scrub the gas and remove the light oil vapors, consisting of benzol, toluol and xylol, reducing to a considerable extent its illuminating value, at the same time reducing in a slight degree only its heating value.

25. In a number of cases where coke oven gas has been purchased by the gas companies, its illuminating value has been restored by the addition of refined benzol to a value even greater than that of the gas before it was first scrubbed.

26. This method of increasing the low illuminating value of this gas has been the result of a requirement for a higher illuminating value, which has been obtained without a corresponding increase in heating value. And the addition of this increase in illuminating value may not be considered at all times to be permanent. Under certain conditions where the unfixed hydro carbon vapors have been removed in a previous washing and scrubbing of the gas, the imparted enrichment from benzol is more effective, as the gas is in a condition to absorb these vaporous hydro-carbons having such a relatively low percentage of saturation. Under these

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conditions the increased illuminating value will stand with rather severe changes in temperature and pressure, and the gas may be considered suitable for general consumption where the illuminating requirements are low, but where a normal heating value is demanded.

27. But, as a general rule, the enrichment or increase in illuminating value of any gas, by the addition of benzol, may not be considered permanent and its addition has a tendency to create a gas variable in quality when delivered to the consumer and objectionable because of carbon deposit in burners and mantles.

28. Carbureted water gas has been used as an enricher for coke oven gas, and its use may be successfully employed where the requirements do not demand an illuminating value above that of unenriched retort coal gas, but otherwise the quantity of carbureted water gas necessary for this enrichment results in too great a proportion of the total amount of gas supplied.

29. Carbureted water gas may be used to advantage to provide any deficiency in supply and to take care of the peak loads where the coke oven gas is produced at a uniform rate from day to day, and provide reserve in times of a depressed market for furnace coke.

CARBURETED WATER GAS

30. An analysis of the records of the Companies manufacturing carbureted water gas, and reporting their results, shows a great variation in both illuminating value and heating value, and proves conclusively that there is no positive relation between illuminating value and heating value.

31. It has been proven, however, that in general the carbureted water gas of the highest average illuminating value has had the highest heating value, as the illumination imparted to the open flame is a function of the quantity as well as the quality of oil used considering the manufacturing apparatus is operated with equal efficiency. It has also been

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demonstrated that the heating value is a factor of the quantity of oil used, but there are limits to the quantity of oil that can be efficiently handled and turned into a constituent gas.

32. Therefore gases of equal illuminating value does not necessarily have equal heating value and vice versa. This is true of the gas when maufactured, without introducing any of the uncertain elements of distribution. Such a condition is due more particularly to the variation in oil efficiencies obtained in producing illuminating value and which are occasioned by different types of generating apparatus and different methods and constituents of operation, as well as the quality of the oil available. These economies or efficiencies are greatly influenced by climatic and temperature conditions, which cause extreme variations between the warm summer months and the cold winter months. And the economic results obtained by scientifically operated plants cannot be expected of all plants throughout an entire State.

33. In the plants of the reporting Companies, the conditions of gas manufacture vary greatly and some variation in the results obtained was, therefore, to be expected. At the same time, the location of the testing station, whether at the works or at some remote point in the distribution system, introduced factors that had to be considered in making an analysis of the results obtained. We believe, however, that the reports indicate what may be considered as good practice, representing fair and average conditions of operation, and that the conclusions drawn are based on representative data.

34. As regulatory requirements have frequently been based on monthly averages, an analysis has been made of the results obtained by months, and from these results have been calculated the heating value imparted to the carbureted water gas per gallon of oil employed in maufacture.

35. From the tests made by six of the Companies the heating value of the gas, as read at the works, for a whole year, averaged 162 heat units per cubic foot, per gallon of oil

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used per thousand cubic feet; while the average obtained in the summer months was 168 and in the winter months 157. The minimum monthly average for all plants was 151 heat units. These same tests show that in one plant the average for an entire month was only 141 heat units per gallon of oil used. The indications are that a yearly average of 150 heat units per gallon, per thousand cubic feet, can be obtained with good operating conditions.

36. It is evident from the reports made by four of the Companies, testing at a point some distance from the works, that the heating value delivered would be somewhat below this figure. These plants show a yearly average of 154 heat units per gallon of oil used, with an average of 167 during the summer months, and an average of 146 heat units during the winter months. The minimum for all plants for any month occurred during January, when 142 heat units per gallon of oil was delivered, with an individual plant average in any month of 139 heat units per gallon.

37. The above figures indicate that, on the basis of the average quantity of oil used in these ten plants during twelve months, at least 150 heat units per gallon of oil during the winter months may be expected when measurements are taken at the works, or 140 heat units per gallon of oil when measured at a point some distance from the works.

38. The quantity of oil used as an average by all the companies was about 3.9 gallons, and if this is considered as a normal quantity to be used, then the average heating value for any one month, of a gas, as read at the works would be 3.9x150 or 585 heat units.

39. The average quantity of oil used in the above deduction represents the conditions when maufacturing gas to meet the present illuminating standard. To meet such a standard requires the manufacture of a gas having an illuminating value of from 6 to 8 per cent. higher than that specified in the standard, on account of the impossibility of manufacturing gas of an exact illuminating value and the necessity for

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an excess in quality to allow for variable losses due to handling, to transmission and to changes in temperature.

EFFECT OF DISTRIBUTION ON THE HEATING AND ILLUMINATING VALUES

40. In addition to determining the heating value and the illuminating value of gas as generated at and delivered from various gas plants, it was deemed essential by the Committee to discover—as far as the present operating conditions would permit—the effect on the quality of the gas of transmission through distribution systems. It was known that losses in the quality of a gas occur during transmission, caused by the scrubbing action on the gas in passing through the mains, which is aggravated by a reduction in temperature and by any increase in pressure. Readings, therefore, were taken, where opportunity permitted, to determine the extent of losses due to these factors.

41. At the beginning of the investigation there was little authoritative data available relating to this question. At the suggestion of the committee, however, some experiments were undertaken to determine the effect of distribution under varying conditions.

42. During a period of eleven months, beginning January 1912, readings were taken by one of the participating Companies (No. 6) of the illuminating value and heating value of carbureted water gas as manufactured, and again as delivered in an outlying district three miles distant, at the end of a pumping main; the initial pressures being from eight to fifteen inches water pressure. These readings were made daily—with some few exceptions—and include some 294 individual tests for both heating and illuminating value. (See Tables II. and III., Appendix A, pages 555, 556.)

The location of the works and the testing stations are shown on the map, on page 613, and it will be seen that at some few points the main is exposed to temperatures of the streams that are crossed, and at other points to atmos-

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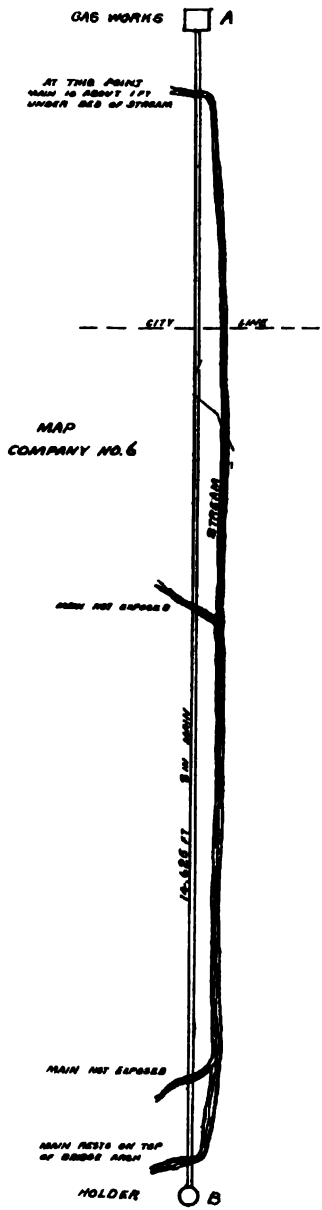

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pheric temperature. The gas was further subjected to atmospheric temperature in an outlying storage holder. Results of these tests indicate the losses in heating value and illuminating value that may be expected at various seasons of the year for gas delivered under similar conditions. The average loss in heating value is 1.4 per cent. and the average loss in illuminating value is 12.8 per cent.

Month	No. tests	Loss in illuminating value		Loss in heating value	
		Candles	Per cent.	B. t. u.	Per cent.
January	20	3.2	14.0	11	1.75
February	16	3.2	13.8	13	2.06
March	26	2.7	11.7	4	0.64
April	30	3.4	14.4	4	0.64
May	31	2.7	11.6	17	2.66
June	30	2.5	10.8	7	1.09
July	31	2.3	9.8	8	1.24
August	29	2.6	11.2	5	0.79
September	27	3.0	12.9	14	2.22
October	26	3.0	12.8	12	1.88
November	28	4.6	18.3	5	0.77
Average			12.8		1.4

43. The daily variations in heating value and illuminating value between Stations A and B are shown by diagrams (page 50). The zero line represents the heating value or illuminating value at A. The solid line curve shows the heating value at B in percentage of the heating values at A. The broken line curve similarly shows the illuminating value at B.

44. Another company (No. 15) made observations of the loss in heating value and illuminating value of gas when pumped under the relative high pressure of fifteen pounds, for a distance of about twenty-three miles. These results cover daily observations for the months of October and November, 1912, consisting of about sixty individual tests. They indicate what may be expected under similar conditions. The readings were made when the ground temperature was about 50° F., and, therefore, do not show the extreme conditions

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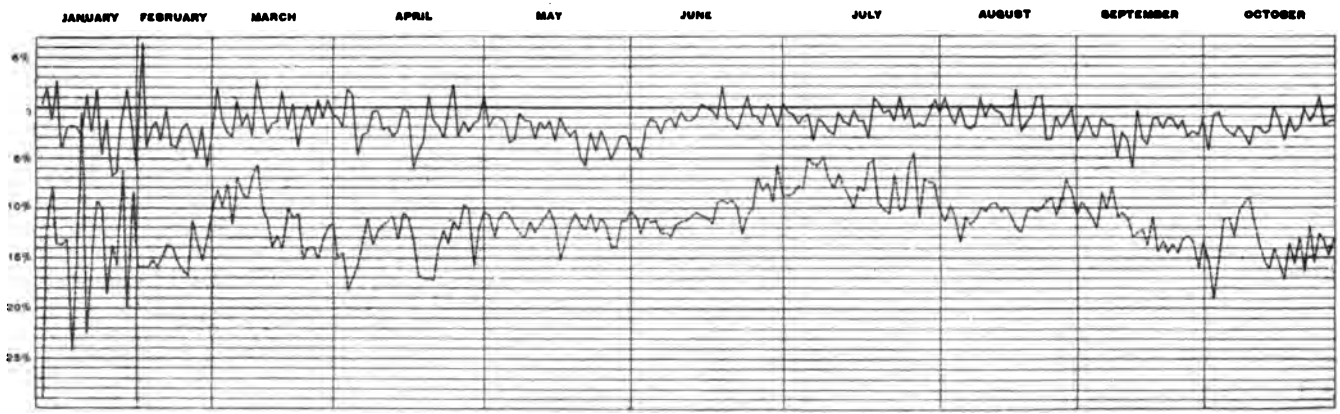

Zero line represents heating value or illuminating value of gas as measured by Company No. 6 at Station A.
Solid line represents percentage of loss in heating value as measured at Station B.
Broken line curve represents percentage of loss in illuminating value as measured at Station B.

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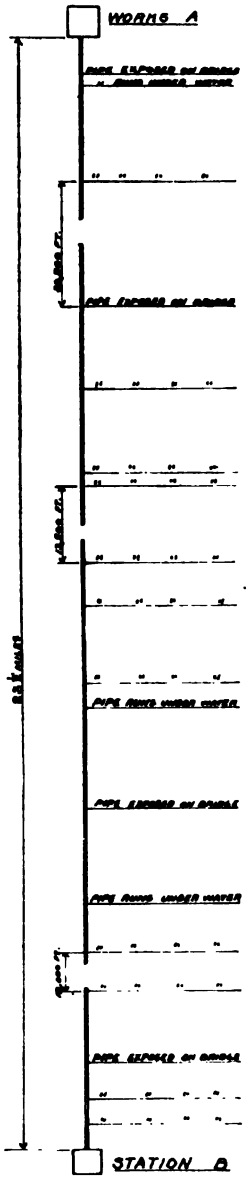

COMPANY NO. 15

8 IN. AND 6 IN. BROUGHT FROM WORKS.

AVERAGE PRESSURE AT WORKS A. 16 LBS.

" " " STATION B. 8 "

SCALE 1 IN = 2 MILES.

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that will be met during the winter months when the temperature of the ground is 32° F. Drawing on page 616 shows how main is exposed both to atmospheric and stream temperatures.

45. The readings made on this high pressure line are summarized below, and it will be seen that the loss due to transmission of gas under these conditions is much more in illuminating value (20.7 per cent.) than it is in heating value (6.05 per cent.).

	Heating value B. t. u.	Illuminating value candle-power
October—1912		
Uncompressed gas	629.0	22.2
Compressed gas	619.0	—
Delivered gas—23½ miles	607.0	17.6
Loss—per cent	3.5	20.7
November		
Uncompressed gas	631.0	21.3
Compressed gas	627.0	—
Delivered gas—23½ miles	577.0	16.9
Loss—per cent	8.6	20.7
Average loss—per cent	6.05	20.7

46. This is in accordance with the expectations, as it is apparent that the decrease in quality is due to the deposition of the unfixed or light oil vapors that are removed from the gas by pressure, and by the low temperature and scrubbing action of the mains.

47. To further confirm these results, at the request of the committee, investigations were also made under the direct supervision of one of its members, on carbureted water gas, manufactured in a large city, in another State, compressed—pressure varying from 10 to 20 pounds—and delivered to several outlying districts. These districts consisted of two smaller cities, several small boroughs and small settlements on both sides of a large river. A large portion of this territory is so situated that the inhabitants would have been unable to obtain gas under any other conditions. The high pressure is reduced and the gas supplied to the two cities through low pressure distribution systems, but the boroughs

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and small settlements are directly supplied by high pressure which is reduced on the consumers' premises. An outline map—page 619—shows the general plan of the system.

48. The gas as manufactured at A averaged about 22 candle-power. At the time of the investigation the gas was compressed to about 16 to 20 pounds pressure as shown in the tables, and then delivered through a high pressure system, consisting of 9,700 feet of 6-inch and 1,875 feet of 4-inch main to a second testing station, B. From this point the 4-inch high pressure main is continued across the river for a distance of 16,625 feet, to a third testing station, C.

49. In crossing the river the main is exposed for a considerable distance, and acquires the temperature of the river water, which at the time of the test approximated 50° F.

50. At Station A, where the gas was compressed, tests were made before and after compression. At Station B tests were made on the gas direct from the high pressure lines before entering the low pressure system. At Station C the gas was tested directly from the high pressure lines.

51. In order to obtain samples of the same gas, the capacity of the mains and the estimated rate of consumption was determined, and the lag was calculated.

52. To determine the illuminating value of the gas, tests were made on standard 60-inch bar photometers at Stations A and B, and on a 60-inch portable photometer at Station C, ten candle-power pentane lamps being used as standards.

53. The heating value of the gas was read on new calorimeters of the American Meter Company, which were compared with each other just previous to testing. All instruments and accessories were tested and calibrated before being used. The humidity of the atmosphere was determined and corresponding corrections made in the calorific values.

54. The temperature of the atmosphere, the temperature of the ground and the dew point of the gas were determined. The temperature of the ground ran from 56° to 58° F., while

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the dew point gave indications as low as 30° F., indicating combined effect due to the compression and cooling.

55. These readings were made over the period from October 31 to November 14, 1912, and the results obtained from day to day, as shown by the following table, substantiate the conclusions presented above—that the illuminating value cannot be maintained if the gas is to be transmitted to outlying districts at relatively high pressures; but that under the same conditions it is possible to maintain the heating value with only slight loss.

56. If these tests were duplicated in the extreme cold weather months of the winter, we might expect even greater losses in illuminating value at Stations B and C.

Loss in illuminating and heating value of carbureted water gas, compressed to 16 pounds and transmitted distances of 2.2 and 5.1 miles:

	Illuminating value candle-power	Per cent. loss	Heating value B. t. u.	Per cent. loss
Initial gas	21.69	—	630	—
Loss due to compression	2.66	12.3	8	1.27
Loss due to transmission—of 2.2 miles	0.74	3.4	2	0.32
Total loss	3.40	15.7	10	1.57
Initial gas	21.69	—	630	—
Loss in compression and transmission—of 5.1 miles	6.68	30.8	11	1.75

COMPRESSION AND TRANSMISSION TESTS ON ENRICHED COKE OVEN GAS, NOVEMBER-DECEMBER, 1912.

57. The Committee also made some investigation of the effects of compression and transmission on the illuminating and heating values of enriched coke oven gas. As there was no such installation in the State, permission was obtained elsewhere to make such a test on a plant consisting of forty ovens and having a capacity for carbonizing three hundred tons of coal daily. A good grade of Pennsylvania gas coal was used, with an average coking period of twenty-two hours. Run-of-oven gas, enriched to about 16 candle-power, flat

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flame, was obtained, using a 90 per cent. benzol enricher. During a part of the test a small amount of high candle-power carbureted water gas was made to help out the deficiency in the make from the coke ovens. In both cases after enrichment at "A," the gas was compressed at "A-1" to between 30 and 40 pounds per square inch, and then delivered to "B," a distance of nine miles. The terminal pressure at "B" was between 26, and 36 pounds. This high terminal pressure was necessary because of distribution to surrounding territory. After compression the gas was cooled to about atmospheric temperature in a condenser, the condensate being removed.

58. At the terminus of the high pressure line the gas was expanded into a holder and distributed at low pressure.

59. The illuminating value and the heating value of the gas at "A," "A-1" and "B" is shown in the tables. These tables also give the losses both actual and in per cent. of original quality of the gas.

60. The ground temperature at "A" was about 47° F. and at "B" it was 49° F. The dew point at "A-1" was 31° F. and at "B" it was 12° F. The average outside air temperature was 39° F.

61. The tests were made with improved American Meter Company calorimeters of the Junker type, and standard 60" bar photometers. All candle-power readings are flat flame value against a standard 10 candle-power pentane lamp. All apparatus was tested and checked for accuracy.

Loss in illuminating and heating value of enriched run-of-oven coke oven gas, due to a compression of 30 pounds and a transmission of nine miles:

	Illuminating value candle-power	Per cent. loss	Heating value B. t. u.	Per cent. loss
Initial gas	16.2	—	598	—
Loss due to compression— 30 pounds	1.8	11.1	20	3.34
Loss due to transmission— 9 miles	4.0	24.7	21	3.51
Total loss	5.8	35.8	41	6.85

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Run-of-oven coke oven gas with an addition of 15 per cent. carbureted water gas:

	Illuminating value candle-power	Per cent. loss	Heating value B. t. u.	Per cent. loss
Initial gas	16.9	—	597	—
Loss due to compression — 40 pounds	2.7	16.0	18	3.02
Loss due to transmission— 9 miles	5.1	30.2	23	3.85
Total loss	7.8	46.2	41	6.87

62. A previous test had been made on the same system, by one of the Committee, in March and April, 1907; and while at that time no determinations in loss of heating value were made, the loss in illuminating value was determined.

63. In addition to the effect of compression and transmission, a test was made on the effect of low temperature by passing the gas through a freezing coil.

64. The following tables give a summary of the results obtained on these tests.

65. The first table shows the effect of freezing on the candle-power of low pressure coke oven gas, carbureted water gas and mixed coke oven gas and carbureted water gas.

	Enriched coke oven gas	Carbureted water gas	Enriched coke oven gas and 20 per cent. carbureted water gas
Initial candle-power	15.92	19.15	16.32
Loss due to compression and freezing to 32° F	2.89	2.63	2.43
Loss in per cent. of initial candle-power	18.2	13.7	17.5

66. The second table shows the effect of compressing to pressures approximating 30 pounds and transmitting through a distributing system 11.5 miles. The first test was on run-of-oven coke oven gas, benzol enriched, and the second test was made on this same gas with a mixture of carbureted water gas, equalling 27 per cent. of the total volume.

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67. Hygrometer readings indicated a dew point of 18° F. on the compressed and delivered gas.

	Enriched coke oven gas	Enriched coke oven gas mixed with 27 per cent. carbureted water gas
Initial candle-power	17.45	17.0
Loss due to compression of 30 pounds and delivered 11.5 miles at high pressure	6.02	4.82
Loss in per cent. of initial candle-power	24.5	28.4

LABORATORY EXPERIMENTS TO DETERMINE THE EFFECT OF COMPRESSION AND FREEZING ON CARBURETTED WATER GAS.

68. To determine further the effect upon the illuminating value and heating value of the gas, certain laboratory experiments were carried on under the supervision of the Committee, with the following results:

69. Carbureted water gas of 23.5 candle-power and 654 B. t. u. heating value, was compressed first to low pressures of three and ten inches of water and then in stages of five pounds each to a total of thirty pounds gauge pressure, and while under compression reduced to a temperature of 35° F. The condensation formed, due to compression and cooling, was removed, and the gas, when expanded again, showed a dew point of 15° F. No serious losses in heating value were found to take place with pressures up to ten inches of water. Such losses, however, became evident as soon as the pressure had reached five pounds and over. At thirty pounds' compression the illuminating value had dropped 32.4 per cent., while the heating value dropped 6.8 per cent. It was noted that the gravity of the gas changed but very little, as shown by a test on an effusion apparatus. The illuminating value seemed to drop uniformly with the compression, while the heating value dropped 30 heat units or the first ten pounds and only twelve additional heat units for the next twenty pounds. The results are shown in detail below:

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Pressure	Candle-power	B. t. u. gross	Loss per cent. Candle-power	Loss per cent. B. t. u.
3 inches, before cooling	23.5	654	—	—
3 inches	20.2	656	—	-
10 inches	20.3	654	—	—
5 pounds	18.1	631	10.6	3.5
10 pounds	16.3	621	19.5	5.0
15 pounds	15.6	624	23.0	4.6
20 pounds	14.95	615	26.2	6.0
25 pounds	14.2	617	29.9	5.6
30 pounds	13.7	609	32.4	6.8

Note.—Original gas passed through 70° F. coil. Compressed gas passed through 35° F. coil.

HEATING VALUE CALCULATED BY ANALYSIS

70. One Company, No. 8, ran its plant (Class C, Table I.) to determine as nearly as may be the heat unit equivalent to the present standard of candle-power. This plant was equipped with á Junker automatic continuous registering calorimeter, which was destroyed by fire before the completion of the full year's test. In addition tests were made daily on both a Sargent and on a Junker calorimeter. Samples of gas were taken and analysis of gas made and recorded. The candle-power was likewise determined on a 60-inch U. G. I. open bar, using No. 7 L. P. Slit Union Bray and new F. Argand Sugg pattern gas burners against candles in accordance with New York legal requirement.

71. Not until the completion of the year's test was any use made of the gas analysis so that the calculated heat units therefrom have special interest as a check.

72. The daily heat unit readings therefore were checked by an automatic instrument self recording and finally by the calculated B. t. u. from the gas analysis. The gas manufactured was carbureted water gas. The gas generating apparatus, 5 feet and 7 feet 6-inch sets, have up and down steam connections and automatic continuously registering pyrometers on superheater. As the plant is a small one the running was intermittent, varying from 8 hours to 23.8 hours.

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Gas oil was used, "28° B." which had been contracted for prior to beginning of test. Anthracite broken coal was used, with some gas-house coke at times for experimental purposes. Oil corrected varied from 3.5 to 4.65 gallons per thousand. Fuel per 1,000, corrected, varied from 37.62 to 40.76.

73. The equivalents used in calculating the B. t. u. from gas analysis were:

Illuminants	2,350.0 B. t. u. per cubic foot
CO	323.5 B. t. u. per cubic foot
H_2	326.2 B. t. u. per cubic foot
CH_4	1,009.0 B. t. u. per cubic foot

The results were as follows:

COMPANY NO. 8.

AVERAGE MONTHLY RESULTS AT WORKS—B. T. U.

	Candle-power	B. t. u. Junkers	B. t. u. Sargent	Calculated from analysis
August, 1911	19.1	617	613	606
September	18.9	610	607	605
October	18.7	594	591	589
November	19.7	633	628	626
December	22.5	645	651	651
January, 1912	22.4	653[1]	656[1]	658[1]
February	22.6[1]	650	653	636
March	20.3	621	625	614
April	18.7	602	601	585
May	19.5	592	593	569[2]
June	19.3	592	591	582
July	17.9[2]	584[2]	584[2]	580

74. The official testing station of this Company was equipped with a Junker calorimeter and 60-inch American Meter Company open bar photometer using similar burners and candles. Gas was analyzed as at plant and B. t. u. calculated with the following results:

[1] Maximum.
[2] Minimum.

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MONTHLY AVERAGES.

	Candle-power	B. t. u. Junker	B. t. u. calculated from analysis
August, 1911	20.0	613	608
September	19.6	605	602
October	19.3[2]	584[2]	581[2]
November	19.9	622	618
December	20.9	642	645
January, 1912	21.1[1]	643[1]	655[1]
February	20.6	631	634
March	19.8	607	610
April	20.4	591	582
May	19.9	590	568
June	20.7	596	586
July	20.6	586	577

75. The Gas Inspector of the State tested the candle-power for the State record twelve times during the period of testing, finding candle-power averaging 20.1. The Company's test for the same days averaged 20.0 candle-power.

76. It will be observed that the B. t. u. calculated from analysis varies from the actual readings made by calorimeters in different seasons. The effect of temperature affects the character of the illuminants remaining in the gas at different seasons. The following calculations were made as a matter of interest. The values of B. t. u. per cubic foot of CO of H_2 and CH_4 were taken as stated heretofore and the actual B. t. u. observed in the Junker calorimeter was assumed in each case as the B. t. u. value of the gas. From these figures the B. t. u. value of the illuminants was calculated with the following results:

[1] Maximum.
[2] Minimum.

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MONTHLY AVERAGES—PLANT.

Date	Plant		Testing station	
	B. t. u. Junkers	Cal. val. of illuminants	B. t. u. Junkers	Cal. val. of illuminants
August, 1911	617	2,458	613	2,399
September	610	2,400	605	2,377
October	594	2,404	584[2]	2,378
November	633	2,410	622	2,385
December	645	2,304[2]	642	2,321
January, 1912	653	2,311	643[1]	2,251[2]
February	650[1]	2,465	631	2,320
March	621	2,408	607	2,325
April	602	2,450	591	2,429
May	592	2,582[1]	590	2,576[1]
June	592	2,449	596	2,454
July	584[2]	2,396	586	2,336

The above results clearly indicate the uncertainty of chemical analysis as a means of accurately determining the calorific value of manufactured gas.

COMPARISON OF CONTINUOUS AND INTERMITTANT OPERATIONS.

77. The manufacture of gas by Company No. 9 was under the same engineering superintendence as Company No. 8. Tests in this case were made only at the testing station over a mile from the manufacturing plant. This plant (Class A, Table I.) runs continually night and day manufacturing carbureted water gas; generators 11 feet and 12 feet reverse steam Lowe type with indicating and recording pyrometers. Gas oil 28° B. using (corrected) 3.41 to 4.34 gallons per 1,000 cubic feet. Anthracite fuel (corrected) 30.45 to 32.67 pounds per 1,000. Calorimeter used Junkers. Candle-power determined by American Meter Company, 60-inch open bar photometer; burners No. 7 L. P. Slit Union Bray and New F. Argand. Analysis of gas was made only occasionally. The results follow:

[1] Maximum.
[2] Minimum.

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MONTHLY AVERAGES.

	Candle-power	B. t. u. Junker
August, 1911	20.8	589
September	20.6	597
October	21.2	619
November	20.4	625
December	20.7	638
January, 1912	20.9	631
February	20.7	621
March	20.7	610
April	20.2	600
May	20.6	589
June	20.6	595
July	20.6	597

78. A comparison of the Company's candle-power reading taken at the time B. t. u. results were taken on thirty days when the State Inspector tested the gas of the Company shows 20.4 candle-power average by State test and 20.8 candle-power by Company's observer.

COMPARISON OF EFFICIENCY OF OPEN FLAME AND MANTLE BURNERS.

79. In replacing the flat flame burner with the mantle burner, it is a matter of importance to determine the relative efficiency of these burners when using the same quality of manufactured gas. It is also important to inquire if similar results are obtained when using mantle burners with unenriched coal gas and the present 20 candle-power water gas. The State Commission, Second District, requires that five cubic feet of carbureted water gas shall give 20 candle-power when burned in the burner best adapted to it, and applicable for general use, when compared with the light of two standard English sperm candles. The candle-power obtained with the normal mantle burner is uniformly greater than obtained in the flame burner even when using only three cubic feet of the same gas. It is customary to state the efficiency of the gas mantle in terms of candle-power per cubic foot of gas used.

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80. Under the supervision of a member of the Joint Committee mantles costing at retail 10 cents, 15 cents, and 35 cents, mantle burners costing 10 cents and 50 cents, and chimneys at a uniform cost of 10 cents were purchased at shops patronized by the general public.

81. These mantles and mantle burners were tested using carbureted water gas from 19.4 candle-power to 21.8 candle-power, at burner pressures varying from one to three inches water. The B. t. u. varied from 603 to 622. Sixty-five separate illuminating power tests were made with the mantles when using this gas. The average candle-power per cubic foot of gas when used in the flame burner was 4.15 candles, while the same gas developed 13 to 21.7 candles per cubic foot when used in the mantle burner. The 13 candle-power test was obtained with gas giving 4.12 candles per cubic foot in the flame burner, yet the same type mantles gave 16.4, 19.1 and 19.9 candles per cubic foot with gas of lower candle-power than 4.12 candles.

82. Seventeen tests, with 2.5-inch burner pressure, were made with these mantle burners and the same type mantles, but using a 14.38 candle-power, unenriched coal gas, equivalent to an efficiency of 2.87 candles per cubic foot of gas when used in the flame burner. The heat units of this coal gas varied from 601 to 607 B. t. u. When this gas was used in the mantle burners from 13.7 to 21.4 candles per cubic foot of gas was obtained.

83. It will be observed that the efficiency of the mantle burner was equally good with either 20 candle-power carbureted water gas or with 14.38 candle-power unenriched coal gas. It will also be noted that the mantle burner is many times more efficient than the flame burner. In some cases the flame burner shows only 13.4 per cent. relative efficiency when compared with the mantle burner using the same gas or as one is to eight nearly.

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84. A mantle burner ordinarily consumes three cubic feet of gas per hour and with 16 candles per foot gives 48 candle-power. To obtain this candle-power with a twenty candle gas in an open flame burner would require twelve cubic feet of gas. This is an hourly saving in gas bills of nine cubic feet. Assuming one thousand hours' burning per annum there is a saving of 9,000 cubic feet of gas, which represents a cash saving of from $8 to $18, depending upon the price of gas. Four mantles per annum would be a fair average for this number of hours' use at an annual cost of from 40 cents to $1.40; as stated, a burner which should give good service for many years costs from 10 cents to 50 cents, and the chimneys 10 cents each. Smaller mantles consuming but one foot to one and one-half feet per hour, where less illumination is required, would show a corresponding saving.

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APPENDIX D

STANDARDS IN OTHER PLACES.

1. Up to 1906 practically all standards for gas, both in this country and abroad, prescribed a certain illuminating value but contained no requirements as to heating value. As early as 1894, however, gas engineers had begun to recognize the inadequacy of a photometric standard and the necessity for determining a calorific value.

2. The earliest date of a calorific standard being established was 1906. Since that time this measure of the quality of gas has been adopted quite generally abroad and in a considerable number of instances in this country.

3. Generally speaking we find no scientific reasons for the figures which have been adopted, and in few cases does there appear to have been any preliminary investigation made along the lines of practical operating experience under varying conditions.

4. Wisconsin, which was the pioneer in the establishment of a state standard of heating value, did, through the Wisconsin Railroad Commission, conduct a series of tests before the adoption of the requirements now in force. These tests, however, did not cover a sufficient period of time or a wide enough variety of conditions to be conclusive. It should also be remembered that long strides have been made in the science of calorimetry during the last year or two, and manufacturing conditions have undergone important changes.

5. At the present time heating value requirements are in force in five states and in some thirty-one cities. A list of the states and cities with their respective requirements follows:

STATES.

Wisconsin	Monthly average 600 gross B. t. u.	Minimum 550
New Jersey.....	Monthly average 600 gross B. t. u.	Minimum 550
Nevada	Monthly average 550 gross B. t. u.	Minimum 500
Washington.....	Monthly average 600 total	Minimum 550
Indiana	600 B. t. u.	

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Cities.	
Aurora, Ill	600 gross
Birmingham, Ala	575 gross
Cedar Rapids, Ia	600
Chicago, Ill	600 gross
Dallas, Tex	633
Detroit, Mich	600 gross
Elgin, Ill	600 net
Ft. Wayne, Ind	550
Indianapolis, Ind	600
Jackson, Mich	600
Joliet, Ill	600 "heat units"
Kalamazoo, Mich	600 gross
Lansing, Mich	600 (low value)
Lincoln, Neb	625
Los Angeles, Cal	600 gross
Milwaukee, Wis	600 gross
Adrain, Mich	Average of 600
Elkhart, Ind	600
Elyria, O	600 "heat units"
Freeport, Ill	Monthly average 600
Freeport, Ill	Minimum 550
Helena, Mont	500
Kankakee, Ill	600 "heat units"
Ottawa, Ill	600
Sault St. Marie, Mich	500
Port Huron, Mich	600 gross
Stockton, Cal	600 gross monthly average
Minneapolis, Minn	600
Minneapolis, Minn	Daily minimum 550
Oakland, Cal	600
Omaha, Neb	600 net
San Francisco, Cal	600
Springfield, Ill	650

6. In 1906 the calorific standard was adopted for Tottenham, the first place in England to have such a standard. This standard was fixed by agreement, but the Gas Light and Coke Company of London was the first to have the heat unit test statutorily applied to town gas. This was accomplished through the Parliamentary Committee of the London County Council advised by Dr. Frankland, Charles Hunt and Dr. Clowes, the figures being set at approximately 500 net B. t. u., with a minimum of 450 B. t. u.

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7. In Europe, Paris has adopted a calorific standard of 528 net B. t. u. and abandoned photometric requirements. The same standard holds in Rheimes. Marseilles has adopted 551 B. t. u. and Milan, Italy, 573 B. t. u.

8. In 1909 German chemists concluded that they ought to have a calorific test, and that the figures should be set at 543 gross B. t. u. with a minimum of 522, these results to apply to tests made at the works. There is even yet no generally accepted standard of calorific value in Germany, although tests have been regularly made in Berlin, Magdeburg, Bonn and Breslau for at least seven years. Zurich was also testing for calorific value at least five years ago.

9. A member of the Committee from personal observation ascertained that many continental cities do not even maintain photometric apparatus for testing gas. Included in this number are Paris, Brussels, Ghent, Bruges, Nuremberg, Stettin, Berlin, Charlottenburg, Warsaw and Zurich. No attention is paid to candle-power. Another authority from personal inquiry and observation confirms this tendency by information derived within six months that the same conditions may be found in Austria and Austria-Hungary as well as Germany and other continental countries.

10. It should be noted that in Continental countries, it is customary to correct the gas volume to O°C (32° F.) and 760 M. M. (30-inch Barometer). The correction to 32° F. instead of 60° used in the United States and by this Committee, means that the standard abroad is actually over 5 per cent. lower than the figures quoted above would indicate. For example, a German gas consumer receiving 543 gross B. t. u. per cubic foot is actually receiving not more than 516 when United States methods of measurements are followed.

11. In South America Colombo has had a heat unit standard of 400 B. t. u. for about five years, and in Buenos Ayres it is required that the net B. t. u. shall not be less than 539.

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12. It will be seen from the preceding figures that the calorific power requirements in Great Britain, on the Continent and in South America are generally lower than those in the United States, due to a recognition of the economic advantages of permitting the use of unenriched coal gas manufactured from such grades of coal as were available.

13. The standards which have been adopted in this country in the past are in most cases in excess of what should be required. They were usually set arbitrarily and without thorough investigation. It is inconceivable that they would have been so fixed with present available raw materials. Reference to Table IV., page 20, shows monthly averages of heating power of gas, enriched to meet the present illuminating power standard as low as 584 B. t. u. and the table in Appendix C, page 43, shows monthly averages of heating power of unenriched coal gas, manufactured, however, from the highest grades of coal, as low as 556 B. t. u. These are not individual readings, but are averages for entire months.

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APPENDIX E

CALORIMETRY AND PHOTOMETRY

Calorimetry

1. Assuming that a suitable calorimeter is employed, that the operator has had reasonable experience and proper instruction, and that the accepted rules of procedure are followed, it is proper to inquire as to the consistency of the readings and the accuracy of the results that will be obtained.

2. One of the smaller companies participating in the investigations has had check tests made on practically every working day during the entire period and with three observers, of whom two were no more than high school graduates; only 5 per cent. of the time was there a difference of 3 B. t. u. between the tests, while on 88 per cent. of the days the difference was 2 B. t. u. or less. The determinations came out exactly the same, decimals being of course excluded, during 32 per cent. of the time.

3. Such results can, however, only be secured by an absolute conformity to operating instructions. The great danger with calorimetric determinations, as in photometric work, is that the operator will drop into the habit of regarding this or that minor detail as unimportant and consequently will finally disregard it altogether. To illustrate, some operators only read their outlet water thermometers to tenths of a degree F., yet an error of 0.1° F. means an error of about 4 B. t. u. in the result.

4. The pressure at which the gas is metered is an important factor, although by some it is considered only a negligible quantity and is left out of consideration. If this is not corrected for, and the gas is delivered to the meter at 3 inches water pressure, the final result will be about 4 B. t. u. too high.

5. The rules as laid down by this Committee in its two pamphlets are not difficult to follow and every point emphasized has a practical value and is necessary to successful determinations. If this is borne in mind there should be no dif-

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ficulty, under ordinary conditions, in obtaining consistency of results.

6. The accuracy of results, however, assuming that the test has been carefully and correctly carried out in every particular, is a different question and demands separate treatment. We shall assume that the operator is endeavoring to obtain the total heat value, or as near thereto as is practically possible, and that he has made all of the usual corrections, *i. e.*, for thermometer error and stem exposure, temperature and pressure under which the gas is measured, and efficiency of instrument. If the inlet water were of the room temperature, and the products of combustion left the instrument also at room temperature, there is still a correction to be applied for the humidity of the air entering the calorimeter. This can be obtained by the use of a psychrometer, the correction then being found in the table furnished by the National Bureau of Standards and published in the Proceedings of the American Gas Institute for 1912. This table, however, consists of two parts: (*a*) Where seven volumes of air are used per volume of gas, and (*b*) where nine volumes of air are used. Since there is at present no practical method of measuring the air passing through the calorimeter, it would seem as if there were an insuperable difficulty at the outset. But if we examine the two tables we find that for ordinary working conditions the differences are not large, as will be seen from the following which have been compiled by taking the difference in B. t. u. between the corrections in the two tables for the same temperature and humidity:

Humidity in per cent.	Room temperature					
	65°	70°	75°	80°	85°	90°
10	1.9	2.2	2.5	2.9	3.3	4.0
20	1.7	1.9	2.3	2.5	3.0	3.5
30	1.5	1.6	2.1	2.2	2.6	3.1
40	1.2	1.5	1.8	1.9	2.2	2.6
50	1.0	1.2	1.5	1.5	1.9	2.2
60	0.7	0.9	1.2	1.2	1.5	1.7
70	0.6	0.6	1.0	1.0	1.1	1.3
80	0.3	0.4	0.6	0.6	0.7	0.8
90	0.1	0.2	0.4	0.4	0.4	0.5
100	0.0	0.0	0.0	0.0	0.0	0.0

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In every case the corrections in part (*b*) of the table are algebraically the greater, but it must be remembered that the low ranges of humidity, as well as the excessive room temperatures, are comparatively rare, at least in this part of the country, and moreover, these extreme conditions do not, as a rule, occur at the same time. If, therefore, the ordinary working conditions are considered, such as a room temperature between 65° and 80°, and a humidity over 30 per cent., it will be seen that the maximum error likely to occur from use of the wrong table is only 1.5 B. t. u. or about one-fourth of 1 per cent. But there is another factor which still further tends to diminish the chances of error from this source. With the exhaust damper set properly and with the air mixer on the burner so adjusted as to give the most perfect combustion (a condition easily judged by the color and general appearance of the flame) the excess of air admitted to the calorimeter is a constant within reasonably close limits, and the seven volumes of air per volume of gas will ordinarily be the mixture employed. Thus it will be seen that, with the aid of the correction table and a humidity determination, the error due to humidity will never be over 4 B. t. u., and, under working conditions, will probably average about 1.5 B. t. u. The application of surface combustion may well be studied with the object of minimizing the quantity of air used in the calorimeter.

7. Another factor which is intentionally disregarded in practical work is the specific heat of the water. Since the custom of weighing the water is now almost universally adopted, any error from this source has usually been considered so small as to be unworthy of attention. In a study of this matter by Leo Loeb, in March, 1911, he states that, in gas calorimetry, the possible variations due to this cause are from 0.13 to 0.25 per cent. This would mean a maximum error of about 1.4 B. t. u.

8. An error which cannot be readily computed is introduced through the fact that the gas is not saturated with

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moisture as it enters the burner. It has always been assumed that gas after passing a wet meter would be very nearly saturated with water vapor, one author stating as the result of his experiments that the saturation was over 98 per cent. Recent investigations seem to render so high a result questionable, but it is the consensus of opinion that the error due to this cause is so small as to be negligible in practical work; it will probably be less than 0.5 B. t. u.

9. One other factor affecting the accuracy of results remains to be considered, and this is loss from radiation. This matter has received considerable attention from the National Bureau of Standards, which has found that if proper baffle plates are placed on the burner, radiation losses may be reduced to about 0.3 per cent., or about 1.75 B. t. u.

10. If we now combine all of these errors, and assume them to be all in the same direction (which is not true) we should have a total maximum error of about 5.5 B. t. u., or less than 1 per cent. The error due to radiation, however, tends to make the observed result too low, while the fact that the gas is not saturated makes the observed result higher than the true figure. The error introduced by the specific heat of water makes the observed result too high, while that due to the unknown volume of excess air admitted may be either a positive or a negative correction. Combining these algebraically, we get a possible error of $+1.5$ B. t. u., or about 0.25 per cent.

Photometry

11. Even with the most complete photometric outfit it is not possible to secure results which are accurate within less than 1 or 2 per cent. This is due to a number of factors which are variable and cannot be corrected for: the personal equation, atmospheric conditions, quality of pentane, deterioration of standard lamps and of discs, varying water line in the meter and inaccuracy of the latter, etc. If this be true of the best type of apparatus, how much more true it is of

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photometers as generally employed, with candles as standards and burners which do not begin to develop the full illuminating power of the gas.

12. In New York State candles have been made the official standard, principally for the reason that it did not seem practical to employ either a pentane or a Hefner lamp in connection with the portable photometer which the commission's inspectors are obliged to use in a large number of places.

13. It appears to have been conclusively established that the candle as a standard is unreliable. Instead of attempting to take up this subject ourselves, we refer to the following as being among the most notable discussions to be found in the voluminous literature dealing with this question—Dutch Photometric Committee, 1894, C. O. Bond's paper on Working Standards of Light, American Gas Institute Proceedings, 1907; Dr. Love's paper on Standard Candles, and the recent work by C. E. Crittenden on the variations in illuminating value of candles.

14. To cite the last authority only, Mr. Crittenden publishes curves showing fluctuations from minute to minute of over 10 per cent. while the average approached closely 2.1 candle-power per pair. If to this be added the errors inherent in a portable photometer, the inaccuracies of a dry meter for photometric work, the troubles furnished by the candle-balance and the use of improper burners, the result obtained is most unsatisfactory. The last item, however, is one of the most important and should receive special consideration.

15. In this country the two states which have given the most thorough study to photometric work have adopted the practice of employing the burner best adapted to the gas to be tested, the burners selected would be either a slit union Bray, a Suggs table top or one of the various styles of Argand burners. The result of this is that, in order to make a satisfactory test, several burners must be tried.

16. While, as a rule, the new style F Argand will give the best results from a water gas of between 17 and 21 candle-

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power, it very frequently happens that, even under these conditions, the Bray burner is superior, and therefore both burners must be tried in every case if a correct result is to be assured.

17. With a coal gas the matter is still worse, for there are at least five styles of Argand burners which may be tried, each adapted to a little different quality of gas and each liable to give the best result on a gas of unknown candle-power.

18. After all of these have been used, and the maximum result secured, is this the candle-power of the gas? No; for there is at least one other burner which might be employed, the Metropolitan No. 2, which would give a much higher candle-power than any of the above.

19. This latter burner has been adopted as official by the London Referees and is recognized by Parliament. It has not met with favor in this country for two reasons: First, its initial cost, which places it beyond the reach of most consumers; and, second, the fact that it gives so much greater candle-power than the burners now used. Neither of these is a scientific reason, for science is not concerned with cost and is concerned with securing as nearly a theoretically correct result as possible.

20. It has been argued that the illuminating value of gas as measured in candle-power is not a definite scientific quantity and in this respect differs from the calorific value. This does not nullify the argument that the manufacturer is entitled to a judgment of his product based upon the best that can be attained therefrom using the most accurate scientific instruments.

21. It is also sometimes urged that illuminating value should be measured with an open flame burner, because the results thus obtained would more nearly represent the value of the gas to the consumer. Such a method would not measure the illuminating value of the gas, but rather the efficiency of the burner used. There are a number of types of open flame

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burners in general use whose efficiency varies from 50 to 90 per cent.

22. If to test the gas the Metropolitan No. 2 burner is used, the consumer will be getting the gas of a certain fixed illuminating value and the measure of light which he will obtain from a given quantity of gas will depend entirely upon the efficiency of his burner.

23. From the above discussion it is evident that a calorimetric test measures much more accurately the heating value of the gas than a photometric test measures the illuminating value. In the test itself, even eliminating the question of burners, the percentage of probable error is much less in a calorimetric test than in a photometric test. It will also be seen that calorimetric tests may be made with sufficient accuracy by other than highly technical men as long as the prescribed rules of procedure are followed.

INSTRUMENTS USED IN INVESTIGATION AND CALIBRATION WORK OF PUBLIC SERVICE COMMISSION

24. The selection of those calorimeters that assure accuracy in determining the heating value of the gas, and yet are simple in operation, received considerable attention from the Committee. For this purpose the work that had been done on the subject of gas calorimetry was reviewed. A study was made of the reports of the Calorimetry Committee of the American Gas Institute made in the years 1908, 1909 and 1912, and in addition consultations were held with the members of the staff of the National Bureau of Standards, Washington, who have had this subject under investigation.

25. It was found that at the present time there are a number of instruments in use and on the market designed to measure the heating value of gas, but employing different underlying principles in their operation. After giving the matter much consideration, it was found advisable to employ calorimeters for this investigation of the water heater type, and only those that expressed directly the heating value of

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the gas, when burning a known quantity of gas and imparting the heat developed to a known quantity of water.

26. Of the calorimeters approved by the committee, only three have been used by the reporting Companies during this investigation. They are the Junkers, the American Meter Company and the Sargent. These instruments have all been calibrated and checked for accuracy at the Commission's laboratory at Albany and in their operation have proved satisfactory.

27. It is interesting to note in this connection the variation in efficiency of instruments after a period of continuous operation for one or two years. We have received figures from the laboratory of the Commission for one instrument tested on November 23, 1910, and again on October 15, 1912. The efficiency in the first case was 99.6 per cent., and in the second case 99.5 per cent. Another instrument was tested on January 27, 1911, and again on November 25, 1912, the efficiency at the first test showing 99.8 per cent. efficiency and in the second case 99.4 per cent. efficiency. Another instrument tested November 18, 1910, and having an efficiency at that time of 99.5 per cent., was tested again on December 16, 1912, about two years later, and showed an efficiency of 99 per cent.

28. The photometrical measurements were made in the usual way and in accordance with the State requirements.

29. The Primary Standard was tested by the Bureau of Standards at Washington by means of an electrical burner, with the following results:

October 22, 1910 ..... Efficiency 99.5 per cent.
April 22, 1912..... Efficiency 99.8 per cent.

30. All wet meters were calibrated prior to the investigation. The calibration of calorimeter thermometers showed that those used in the investigation were of high class, the corrections applicable being very small.

31. In the table following the efficiencies of the calorimeters of the participating Companies are given. Column I shows

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the efficiencies as determined against the Primary Standard in the laboratory of the Commission at Albany, before the companies began to report to the Committee. Column IV gives the results against the Primary Standard after the companies ceased reporting. There is thus an interval of at least fifteen months between the results in Column I and IV in nearly every instance, and in some cases over two years. The efficiencies given in Columns II and III were determined by the use of the Secondary Standard at the plants of the companies by traveling gas inspectors of the Commission and at intervals of several months.

EFFICIENCIES OF CALORIMETERS DETERMINED BY PUBLIC SERVICE COMMISSION

Company No.	Column I vs. primary standard	Column II vs. secondary standard	Column III vs. secondary standard	Column IV vs. primary standard
1	99.8	—	99.6	99.3
2	99.3	98.8	99.2	99.4
3	99.8	98.5	99.6	99.4
4	99.5	99.7	99.0	99.0
5[1]	99.3	—	—	—
6	99.2	97.7	99.6	98.4
6	99.7	—	98.9	99.1
7	99.5	99.6	—	99.3
8[2]	99.4	99.4	99.4	99.6
8	99.5	98.8	99.5	99.2
8	99.1	99.4	98.7	99.3
8	99.6	—	—	99.5
9	99.3	—	—	99.6
10	99.3	99.1	—	—
11	99.6	99.9	99.8	99.8
12	99.3	99.0	99.5	98.7
13	98.2	99.2	97.6	99.0
14	99.3	—	—	99.0
15	99.8	—	—	—
16[1]	—	99.0	99.2	99.3

[1] Same instrument.

[2] The three tests opposite Company No. 8 showing accuracies 99.4, 99.4, 99.4, were made September, 1912, February, 1912, and July, 1912, respectively.

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32. These tests not only indicate that the variation in efficiency of a calorimeter is slight, but also that a more satisfactory result is obtained when this calibration is performed in the laboratory of the Commission, which has been especially equipped for just such work.

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APPENDIX F.

REPRINT OF CALORIMETRIC RULES, REGULATIONS AND SPECIFICATIONS

Adopted May 6, 1910, by the Joint Committee on Calorimetry, representing the Public Service Commission and Gas Corporations in the Second Public Service District, New York State.

INTRODUCTORY NOTES

(1) A preliminary inquiry into the heat units of gas supplied in New York State was made in 1908 and 1909 by the Division of Light, Heat and Power of the Public Service Commission, Second District, by direction of the Commission. The inquiry was conducted under the immediate supervision of Mr. Charles H. Stone, the Chief Inspector of Gas.

(2) The results of the determinations were submitted to the Commission in a report by the Chief of the Division, Mr. Henry C. Hazzard, under date of October 29, 1909.

(3) Under date of December 8, 1909, the Commission addressed the following communication to each gas corporation:

"Albany, December 8, 1909.

"*To Corporations Engaged in Furnishing or Distributing Coal Gas, Water Gas, or Mixed Gas*:

"By resolution duly adopted, this Commission has appointed February 1, 1910, as the date for a conference with representatives of gas companies on the subject of standards for the measurement of the value of gas.

"The particular object of the conference is to obtain an interchange of views on the necessity for a calorific standard, and on all questions necessarily incidental thereto.

"A preliminary inquiry into the subject has been completed, the results of which are embodied in a report by the Chief of Division of Light, Heat and Power. For your information therein we are sending you under separate cover a printed copy of this report.

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"The conference will begin at 2 P. M., in the hearing room of this Commission, at the Capitol, Albany, on the above mentioned date, and if necessary will be continued the following day. You are respectfully requested to have a representative present.

"Very truly yours,
"J. S. KENNEDY,
"Secretary."

(4) The conference on February 1, 1910, decided upon the desirability of establishing a joint committee under whose immediate charge and direction, subject to the approval of the Commission, the inquiry should be concluded.

(5) The Commission appointed to serve on such committee:

Messrs. Henry C. Hazzard, Chief of Division of Light, Heat and Power.
Howard H. Crowell, Engineer of Division of Light, Heat and Power.
Charles H. Stone, Chief Inspector of Gas, Division of Light, Heat and Power.

The gas corporations represented at the conference appointed to serve on such committee:

Messrs. R. M. Searle, Rochester Railway and Light Company.
W. R. Addicks, Westchester Lighting Company.
T. R. Beal, Poughkeepsie and Newburgh Light, Heat and Power Companies.
J. C. DeLong, Syracuse Lighting Company.
W. T. Morris, United States Gas and Electric Company.
M. W. Offutt, Mohawk Gas Company.

(6) This Joint Committee, of which Mr. Henry C. Hazzard was elected Chairman on February 11, 1910, appointed a sub-committee of three, consisting of Messrs. W. R. Addicks, James C. DeLong and Charles H. Stone. The sub-

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committee in the discharge of its duties submitted the following report, which was duly adopted by the Joint Committee at a meeting held March 11, 1910, and revised May 6, 1910, and ordered printed for the guidance of those participating in the inquiry:

REPORT OF A SUB-COMMITTEE OF THE JOINT COMMITTEE OF NINE.

REPRESENTING THE NEW YORK PUBLIC SERVICE COMMISSION, SECOND DISTRICT, AND REPRESENTATIVES ELECTED AT A MEETING OF GAS COMPANIES IN ALBANY, FEBRUARY 1, 1910

At a meeting of the Joint Committee held in Albany February 11, 1910, resolutions were adopted providing for the appointment of a sub-committee consisting of Mr. Addicks, Mr. DeLong and Mr. Stone to prepare and submit to the Joint Committee:

(1) Specifications for a primary standard calorimeter;

(2) Rules and regulations for the installation and operation of calorimeters at plants of gas corporations;

(3) Suggestions as to suitable types of calorimeters for use, when checked against the primary standard, at gas plants.

In accordance with the above, your sub-committee begs leave to report as follows:

I.

HEATING VALUE OF GAS.

(1) The definition of the heating value of gas adopted by your sub-committee for the purposes of this report and the investigations to be hereafter conducted is that given by the American Gas Institute, Vol. III., 1908, page 383, as follows:

> "The heating value of a gas is the total heating effect produced by the complete combustion of a unit volume of

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the gas, measured at a temperature of 60 degrees Fahrenheit, and a pressure of 30 inches of mercury, with air of the same temperature and pressure, the products of combustion also being brought to this temperature.

"In America the unit of volume is the cubic foot and we recommend that the heating value be stated in terms of British Thermal Units per cubic foot of gas."

II.

PRIMARY STANDARD—TO BE MAINTAINED AT LABORATORY OF THE COMMISSION AT ALBANY.

1. The Primary Standard shall be a new instrument, and shall consist of the calorimeter proper, as manufactured by Junkers & Company, Dessau, Germany, and as illustrated by Instrument No. 1221, now in possession of the Public Service Commission of the Second District, State of New York.

2. The meter for measuring the gas shall be a wet meter, having a drum capacity of 1/10 of a cubic foot for each revolution, and with an outside gauge glass for indicating the water level. The dial shall read in tenths, hundredths and thousandths of a cubic foot. This meter shall be of the size and pattern supplied by the American Meter Company, fulfilling the above requirement.

3. The thermometers for use in determining the temperature of the water entering and leaving the calorimeter shall be of the design recommended by the Calorimetry Committee of the American Gas Institute. They shall have a range of from 60 to 110 degrees F., shall be subdivided to read 1/10 of one degree, and shall have an auxiliary division at 32 degrees F. for checking the ice point. They shall be calibrated throughout their entire range.

4. The thermometers for reading the temperatures of the gas, the atmosphere and the exhaust products shall be graduated in degrees F., shall be accurate to within one-half (½) of

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one degree, and shall be calibrated throughout their entire range.

5. Gas used for standardizing purposes shall be stored in a holder of not less than 50 cubic feet capacity.

6. The gas pressure at the inlet of the meter shall approximate existing normal distribution pressure supplied to consumers of artificial gas, and this pressure shall be added to the barometric pressure and taken into account when making the barometric corrections as indicated hereafter.

7. The gas governor placed between the meter and the burner shall be of the float type now supplied with the Junkers Calorimeter.

8. Arrangements shall be made for accurately weighing the water passing through the calorimeter, and the balance employed shall have a capacity of ten (10) pounds avoirdupois, and give the correct weight at that capacity to within 0.001 of one pound.

9. The calorimeter, balance, weights and thermometers shall be carried to Washington and there standardized and calibrated by the National Bureau of Standards. The gas meter shall be tested against a cubic foot bottle bearing the seal of the said National Bureau of Standards.

10. The water supply to the calorimeter shall be filtered, and so arranged that the water entering the calorimeter shall be of a uniform pressure and temperature, and that temperature shall be within two (2) degrees of the temperature of the atmosphere surrounding the calorimeter, and of the exhaust products leaving the calorimeter.

11. The gas as metered and entering the calorimeter shall have approximately the room temperature, and shall be corrected to 60° F. and 30 inches barometric pressure, the latter to be read from U. S. Signal Service type of barometer.

12. The calorimeters shall be operated with the minimum quantity of air to effect complete combustion of the gas, which shall be burned at a rate giving the maximum calorific efficiency.

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13. Corrections shall be made for atmospheric humidity.

14. The entire apparatus shall be installed in a proper room of the Laboratory of the Public Service Commission, Second District, in Albany.

III.

SECONDARY STANDARD—TO BE USED IN CHECKING THE CALORIMETERS OF THE GAS COMPANIES IN SITU.

1. The Secondary Standards used by the Public Service Commission, Second District, New York, shall consist of calorimeters and accessories which with the operating methods employed shall give, within 2 per cent. the heating value of the gas, as determined by the Primary Standard heretofore recommended.

2. The Secondary Standards shall be checked against the Primary Standard at such intervals as will maintain the calorimeters and accessory apparatus in condition to fulfill the said 2 per cent. requirement, and the results of such tests shall be recorded and filed.

3. The Secondary Standards shall be used for checking the calorimeters of the companies engaged in experimental work relating to the heating value of artificial gas; said checking should be made not oftener than once in thirty (30) days, and shall be made at least once in ninety (90) days.

IV.

GENERAL SPECIFICATIONS AND RECOMMENDATIONS FOR CALORIMETER INSTALLATIONS BY GAS COMPANIES

1. We recommend the adoption of a calorimeter of the water heater type (see paragraph 2), which when new shall be tested against the State's Primary Standard, and we feel that an instrument should be required to have an efficiency within 2 per cent. of the Primary Standard (see page 648).

In determining the calorific value of the gas we recommend:

(a) The measuring of the gas in cubic feet (see paragraph 9).

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(b) Taking all temperatures of air, gas and water with Fahrenheit thermometers (see paragraph 22).

(c) Weighing or measuring the water in pounds and hundredths of a pound (see paragraph 30).

(d) Correction of the volume of the gas to standard volume, as expressed when measured at a temperature of sixty (60) degrees Fahrenheit, and barometric pressure of thirty (30) inches of mercury (see paragraph 29).

(e) Expressing the result of all calorific determinations in British Thermal Units (B. t. u.'s) [see page 648].

(f) That at this time, with the information before us, we believe that a calorimeter in commercial use may be expected to give results with an efficiency within 3 per cent. of the Primary Standard, in which case it should be held to be commercially correct. A record should be kept of the periodic tests made by the State's Inspector with the Secondary Standard.

Calorimeter Proper.

2. The calorimeter proper shall be an instrument that transmits directly the heat evolved by the burning gas to a quantity of water: it shall at this writing be of a design operating on the principle as illustrated by that of the Junkers Gas Calorimeter. This calorimeter shall be accompanied by accessories that shall measure definitely the gas burned; the water heated and the temperatures of the gas, water, air and exhaust products.

3. The apparatus should be designed to give a constant head of water on the Calorimeter. This head should be maintained by having a weir overflow on the inlet at some distance above the top of the calorimeter, and a weir overflow at the outlet. The rate of flow through the calorimeter should be regulated at the inlet by means of a cock with graduated scale.

4. The calorimeter should be so built that the water will circulate freely, and will be equally distributed throughout the apparatus. Baffle plates should be so arranged that the water

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will be thoroughly mixed before coming in contact with the bulb of the outlet thermometer, insuring a correct average reading. The design should be such that air pockets cannot form in the water space of the calorimeter.

5. The calorimeter should be made of bright polished metal, air jacketed in all its parts.

6. There should be a damper in the exhaust gas flue which can be easily adjusted, and which cannot be moved by a slight jar.

7. The calorimeter should be mounted at a height sufficient to make it easy to put the burner in place, and on legs with a spread great enough to insure a firm base.

8. It may prove desirable in practice to have water thermometers on the same level, to facilitate readings, as recommended by the Calorimetry Committee of the American Gas Institute. The openings for thermometers should be large enough to take a No. 4 rubber stopper.

Meters.

9. For a meter, we recommend a wet meter, and one registering 1/10 cubic foot per revolution.

10. The large dial should be divided into 100 equal parts, with every tenth part distinctly marked to facilitate reading. In addition to the large dial, there should be a smaller dial to register the number of revolutions of the large hand; this dial should register tens, units and tenths of a cubic foot.

11. The face of the meter should be enameled and no glass used on the front, thereby preventing error due to parallax. The face of the meter should be easily removable, in order to get at the shaft and the stuffing box on the shaft. This stuffing box should be of a size large enough to be easily packed.

12. The large hand of the meter should be well pointed, and not extend to the outer end of graduations of the meter dial. The meter should have leveling screws.

13. Two leveling tubes, placed at right angles to each other, should be securely fastened to the top of the meter.

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14. The meter should have an outside gauge glass showing the water level. This glass should not be less than ⅜-inch, nor more than ¾-inch, inside diameter, as it is necessary to have the glass large enough to be readily cleaned, and small enough that the meniscus formed by the water can be accurately read. The openings from the gauge to the meter should be unobstructed, and of a size to correspond with the size of the gauge glass. A fixed point to show the correct water level, reading to the bottom of the meniscus, should be put on the outside of all water level gauge glasses.

15. For convenience, a standard 3-light meter union should be used on all meters, and hose nipples for ⅜-inch hose should be furnished with the unions.

16. The meter should be provided with an opening for the addition of water when needed. This can be done by using a pet cock, with a small covered funnel mounted on top, connected to the top of the gauge glass support.

17. An opening must be left for a thermometer in or near the gas outlet. This thermometer should have a metal case and read to one degree Fahrenheit, with a range of from about 50 to 100 degrees, and accurate to within ½ degree.

18. An opening with a plug connection should be left on the bottom of the meter to drain it when so desired.

19. The number of joints liable to cause leakage should be reduced to a minimum.

Gas Pressure Regulator.

20. The pressure of the gas when burning in the calorimeter should be absolutely uniform to obtain correct results, and any small regulator that will maintain this uniform pressure will be satisfactory. We recommend the use of a small wet governor, similar to the one supplied with the Junkers Calorimeter. This will give excellent regulation, and will operate without chattering. Such a regulator should be constructed so as to be readily weighted for altering the delivered pressure.

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Burners.

21. The burner should be a long tube Bunsen, having a spreader on top, and adjustable air mixer which can be easily reached when burner is in position in the calorimeter. The burner should be provided with a stop-cock. The burner should be attached to the calorimeter in such a way that the gas flame cannot impinge on the interior body of the calorimeter, and when the burner is set at its correct position it should be so fastened that it cannot be accidentally shifted. The condition of the same should be observable by the operator, either directly or by means of a reflecting mirror.

Thermometers.

22. Accurate thermometers are the most important accessories to correct calorimetry.

23. The thermometers for reading water temperatures should be of high grade quality, and should read accurately within 1/10 of a degree Fahrenheit.

24. The thermometers should be graduated from 60 to 110 degrees Fahrenheit, each degree to be divided into tenths, with short, distinct graduations. The thermometers should be so accurately made that in ordinary commercial work corrections may be neglected. With each thermometer should be provided a calibration curve, which should enable very accurate results to be obtained whenever it was deemed necessary to make these corrections.

25. This matter of high-grade thermometers for calorimetry work has been taken up with several thermometer makers by the American Gas Institute's Calorimetry Committee, which reported that Messrs. Hohmann & Maurer, of Rochester, N. Y., are now delivering a thermometer that has been built according to its recommendations. The thermometers have a range of 60 to 110° F., and graduated to 1/10 degree, having an auxiliary division at 32° F., which is convenient for carefully checking the ice point. These thermometers are carefully made and have a bore that is exceedingly uniform

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and accurate. This Committee hopes that other makers will place on the market similar instruments.

26. The error of 1/10° above mentioned may seem to be a small matter, and it is in most measures of temperature, but when the calorific value of an artificial gas is determined with a rise in the water temperature of 15° F., a difference of 1/10° means an error of 1/150 of the total heat of the gas, or about four (4) B. t. u.'s.

27. When doubt arises as to correctness of thermometers, we recommend their calibration by the National Bureau of Standards at Washington.

28. Telescopic sights for reading thermometers should be provided, as much more accurate readings can be obtained in this way.

Barometer.

29. Corrections for variation in barometric pressure should be made in measuring the volume of the gas. This pressure should either be obtained by means of a mercury column barometer or by a recently calibrated aneroid barometer. Where it is possible barometer readings should be checked occasionally with readings of the Government Weather Bureau of the city in which the readings are made. Where no barometer is available, it may be possible to get fairly accurate figures on pressure by obtaining from the local Weather Bureau the barometer readings for the day, and correcting for variations in elevation.

Water Supply and Measurement.

30. The control of the temperature of the water supply is very important in calorimetry, and this temperature should be approximately that of the room in which the observations are being made. Water obtained from an ordinary house piping system is apt to be variable in pressure and temperature, due to the uneven consumption in other parts of the building, and possible exposure of the water main to the ex-

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treme temperatures of the ground or atmosphere. This control of temperature or pressure may be readily obtained by providing a permanent water supply tank in the upper part of the calorimeter room, that will contain enough water to enable the readings for the day to be made. A flat tank of large horizontal area is preferable to a deep vertical tank. The exposed surface allows the water to come to the temperature of the room more readily, while the shallow depth has less effect on the head as the water is being used.

31. Should a number of continuous readings be made that will require more water than is contained in the overhead tank, a simple coil gas water heater may be employed to raise the temperature of the water supply to the overhead tank, so that it will enter this tank at approximately the temperature of the room. The tank will then act as an equalizer and assist in maintaining a uniform temperature and pressure of water entering the calorimeter.

32. Water may be collected and weighed in thin sheet metal containers, holding about nine (9) pounds of water. This size container will hold all the water required in burning 0.2 of a cubic foot of ordinary illuminating gas, with a range of about fifteen (15) degrees Fahrenheit in temperature between the inlet and outlet water. The scales, or balance, employed should have a capacity of at least ten pounds, should read to 1/100 of a pound, and should be calibrated and certified to as being correct by proper authorities.

33. Should it be desired to measure the water volumetrically, instead of weighing it, graduated vessels may be employed that will read accurately the water passed through the calorimeter to within 1/100 of a pound. Such vessels, however, shall be approved by the Commission and calibrated (by State or National authority) at 60° F. and accompanied by a curve to correct for other temperatures.

Gas Piping and Tubing.

34. Gas connections for a calorimeter should consist of metallic piping or tubing where possible; rubber tubing is

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not advisable, but when necessary, the lengths used in conducting the gas should be as short as possible, and they should be thoroughly saturated with gas before a test is made.

Humidity.

35. It may be desirable to have the state of the humidity of the atmosphere during the test, in which case percentage readings may be made from wet and dry bulb thermometers. For accurate work these wet and dry bulb thermometers should be arranged so that the average humidity of the room may be obtained. This may be done by having a whirling wet thermometer, or having a constant current of air impinging upon the wet bulb from an electric fan; or, a more perfect instrument in the form of an Assman Psychrometer may be obtained. These humidity readings of the atmosphere will not be found ordinarily necessary in commercial calorimetry, but may be useful if it is desired to make corrections for heat absorbed in saturating the products of combustion.

Calorimeter Cabinet.

36. To facilitate the operation of the calorimeters at the various gas plants, the calorimeters should preferably be installed in a cabinet, similar to that recommended in the Report of the Calorimetry Committee of the American Gas Institute, as contained in the American Gas Institute Proceedings, Vol. IV., 1909, pages 205 and 206. This sketch represents a typical cabinet, suitable for use in some convenient building, either at the gas works or gas office, and of such a design that when the calorimeter is once placed and connected up, it may be kept clean, protected and ready for use at all times.

37. In construction, the cabinet should be made as dust tight as practicable. Where there is not enough head room for a vertical sliding door, horizontal sliding or folding doors may be substituted. This cabinet should provide for an overhead water tank, and may be most conveniently located adjacent to a sink and water supply.

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38. The gas supply line to the calorimeter should have a purging connection. All cocks controlling the gas and water supply should be inside of the cabinet, and the cabinet should be kept closed and locked when not in service.

39. This cabinet shall not be near any gas flame, register or other object radiating heat; direct sunlight shall not be allowed to strike upon it, but the thermometers and meter shall receive sufficient reflected artificial light to enable them to be easily read. Since drafts must be rigorously excluded, it is better, wherever possible, to set aside a room solely for the use of the calorimetric outfit.

40. The adoption of such an installation will enable a calorific reading of the gas to be made in a very short time, and will warrant the best of care being taken of the calorimeter and of its accessories.

41. After installation and before undertaking investigations involving experimental data, the above equipment should be inspected by the Chief Inspector of Gas of the State Commission and have the approval of the Commission.

V.

DIRECTIONS FOR OPERATING A CALORIMETER.

1. On unpacking the Calorimeter, see that it is cleaned inside and out, and free of packing material.

2. Study carefully the erecting directions and cuts and see that all parts are included.

3. Handle the thermometer with the *greatest of care.*

4. The Calorimeter should be set up in a quiet, light and well-ventilated room or cabinet, which is free from draughts and in which the temperature can be maintained constant at not less than sixty degrees Fahrenheit. The room should be provided with a sink and with a good supply of running water. It is advisable to have a large shallow overhead covered tank, from which the water supply can be taken. Should the tank capacity be small and not hold enough water for a prolonged series of readings, a small gas water heater may be employed

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as already noted to bring the water to approximately the room temperature. It is desirable to use water in the Calorimeter that is clear and free from suspended matter, therefore, a filter should be installed in the water supply line before it enters the overhead tank.

5. If only a single test is desired, gas may be taken from the house piping, but if an average value is required, a small gas holder, or averaging tank, should be used, and the gas flowing into the holder adjusted to a rate of flow to just fill it in the time during which the sample is to be taken. Care should be taken to have a short service to this holder in order than an average sample of gas may be obtained, and if the sample be taken from a line on which there is no considerable consumption, see that this line is thoroughly purged before sampling. It is recommended that the gas be metered at a pressure not to exceed 2 inches of water; if this is not obtainable, it is advisable to insert a holder or diaphragm governor in the supply line to reduce the pressure to within this limit.

6. Set up the calorimeter so that the overflow and outlet water can be easily led to the sink. Make water connections with rubber tubing, being careful not to cramp the tubing. To avoid air currents caused by the movement of the observer's body, set up the calorimeter so that the water supply and waste may be easily adjusted and that all temperatures may be readily observed. Lead the outlet water to a waste funnel supported a little above the top of the copper or glass container used in collecting the water, so that the water can be shifted from the funnel to the container and back without spilling.

7. Set up the gas meter facing the observer and level it carefully. Then adjust the water level of the meter, both inlet and outlet being open to the air. To do this, remove the plug from the dry well, open the funnel cock and disconnect the tubing on the outlet of the meter. With one finger over the dry well turn on the gas a little and by removing and replacing the finger see that there is no water in the dry well. If water

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be found therein it most be blown out by gas pressure. Notice whether the water in the gauge glass moves freely, as, if it does not, the meter is out of order. Now remove the finger from the dry well and add or remove water (through the funnel or by the cock under the gauge glass) until the lowest edge of the meniscus just touches the scratch on the gauge glass, or is even with the fixed pointer. Replace the plug in the dry well, close the funnel valve and connect the governor. If the meter has been filled with fresh water the gas must be allowed to burn at least two hours before making a test. When the water in the meter is saturated with gas, twenty minutes should be sufficient.

8. Fill pressure regulator with water, then connect it to the calorimeter burner. Metallic tubing is preferable, but when rubber tubing is used to connect meter, pressure regulator and burner, connections should be as short as possible, and should be saturated with the gas.

9. Turn on gas and allow it to burn for 5 or 10 minutes with the burner on the table. Shut off gas at burner and watch hand on meter for leakage. Be sure that all leaks are stopped before attempting to make a test. Start water running through the calorimeter at a rate of about three pounds per minute. Then regulate the gas to flow at the rate of 4 to 7 feet an hour, as may be found by experiment to give the highest result with the gas to be tested, admitting enough air through the burner so that the flame shows a faint luminous tip, then insert the burner at the proper height in the calorimeter and observe again the condition of the flame to see that it is all right, using a mirror.

10. The excess of air passing through the calorimeter is controlled somewhat by the position of the damper in the exhaust port, and the best results are obtained by having the excess air as low as possible and still maintaining complete combustion of the gas. Such position has heretofore been found to be about one-fourth open with those calorimeters

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already investigated; care must be exercised to determine this for each calorimeter.

11. Water should be regulated so that there is a difference between the inlet and outlet temperatures of about 15 degrees Fahrenheit. The temperature of the inlet water should vary but little when an overhead tank is used and the water maintained at room temperature. Be sure that both overflows are running.

12. Before making the test the barometer, temperature of the gas at the meter, temperature of room and temperature of exhaust products should be recorded. It is desirable to have the temperature of the inlet water and temperature of exhaust products as nearly as possible at room temperature, in order to establish more nearly a thermal balance; the difference in these temperatures should never exceed five degrees.

13. Next allow the gas to burn in the calorimeter until a thermal balance is established, or until there is the least change in the inlet and outlet waters.

14. The test may now be started by shifting the outlet water from the funnel to the container just as the large hand on the meter passes the zero point. Readings are then made of inlet and outlet thermometers, making the readings as rapidly as the observer is able to record them during the consumption, preferably of 2/10 of a cubic foot of gas. At least ten readings should be made of both inlet and outlet water temperatures. Water is again shifted from the container to the waste funnel as the hand passes the zero point the second time. Water is then weighed, or measured. The uncorrected heating value per cubic foot is obtained by multiplying the difference of the averages of inlet and outlet temperatures, by the number of pounds of water and dividing by two-tenths. This quantity is divided by the correction factor for barometer and temperature, obtainable from tables, to give the heating value at 30 inches pressure and 60 degrees Fahrenheit. The weight or contents of container should be

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obtained while the inside is wet. This may be done by filling it with water, emptying and shaking for about five seconds in an inverted position. This will do away with any correction where several consecutive tests are required with same container.

15. A second, and perhaps a third test is advisable, and these should be made without disturbing the existing conditions, provided all readings are within the above prescribed limits. In practice the operator should get consecutive results on the same holder of gas within ten (10) B. t. u's. Under such conditions an average of the results may safely be taken.

Results as Obtained by Calculation.

16. The method of calculating the calorific value of the gas from the observations indicated is very simple when all readings are made in English units, as recommended, and entered in some form conveniently arranged. A simple record sheet is illustrated in the American Gas Institute Proceedings, Vol. III., 1908, page 320.

17. The averages of the inlet and outlet water temperatures are made and any correction for thermometer error allowed for. The difference in these averages should give the rise in temperature of the water. This rise in temperature of the water is then multiplied by the number of pounds of water passed through the calorimeter during the test. The product of these two is then divided by the quantity of gas burned, either 0.1 or 0.2 of a cubic foot as may be. This quotient will give the heating value of one cubic foot of gas in B. t. u's. at the indicated temperature and barometric pressure. To correct this to 60° F. and 30 inches pressure, divide by the "Correction Factor" for the indicated temperature and pressure as obtained from some standard table, a copy of which may be found opposite page 373 of the Proceedings of the American Gas Institute, Vol. III., 1908. The final result will be corrected heating value of the gas tested, in B. t. u's.

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18. Expressing the above in a formula we have:

$$\text{B. t. u's. per cubic foot} = \frac{G}{W \times T}$$

W=Weight, in pounds, of water passed.

T=the average difference in temperature, in degrees Fahrenheit, between inlet and outlet water.

G=corrected volume of gas burned, in cubic feet.

Use of Computer.

19. The labor of making the calculations for determining the heating value from observations of a calorimeter may be lessened by the use of a heating value computer. The computer consists of a circular slide rule, with divisions corresponding to the readings made on the calorimeter. This computer gives the corrected heating value of a cubic foot of gas in B. t. u's, having the barometer and temperature of the metered gas, and the difference in temperature between the inlet and outlet water and the pounds of water passed. This computer is designed to operate within the limits of from 300 to 800 B. t. u's. Should a gas of a lower or higher heating value be measured, the computer can still be used by dividing or multiplying one or the other of the factors in its computation. A cut of this computer may be found on page 373, Vol. III., Proceedings of the American Gas Institute.

Care of Instruments.

20. The calorimeter, being a delicate and sensitive instrument, should be very carefully cared for when not in use. If the instrument is set up permanently, provision should be made that it be not disturbed by anybody except the operator. If the instrument is not erected permanently, when dismantled it should be carefully cleaned inside and out and the thermometers removed and carefully packed in cotton.

21. It seems hardly necessary that instruction should be given for the care of such an instrument, but certain precautions should be noted.

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Precautions—"Don'ts."

22. Don't place lighted burner in calorimeter when water is not running through the calorimeter.

Don't shut off water while gas is burning, but if water is accidentally shut off, then shut off the gas quickly, to avoid breaking thermometers.

Don't move suddenly near instrument during test. Slight drafts thus caused will vary outlet readings and vitiate test.

Don't fail to check daily the water level in the gas meter.

Don't forget to test meter and all connections daily for leakages.

Don't erect the calorimeter too close to any heating appliances, where radiant heat might affect the readings.

Don't make the test with the inlet water temperature over 5 degrees above or below the temperature of the room.

Don't fail to fill the overhead tank with water when through testing so that it will be ready for the next test.

Note:

23. That an error of 1/10° F. in water temperature means an error of about four B. t. u's. in the gas.

That an error of 1/100 of a pound of water when burning 0.2 of a cubic foot of gas in the test means an error of about 0.9 B. t. u's. in the gas.

That an error of one degree in the temperature of the gas means an error of about 1.8 B. t. u's.

That an error of 1/10 of an inch in Barometer reading means an error of about 2 B. t. u's.

That when metering the gas, each additional inch of water pressure to which the gas is subjected means an error of about 1.5 B. t. u's.

VI.

SUGGESTION OF SEVERAL TYPES OF CALORIMETERS SUITABLE TO USE WHEN CHECKED BY THE PRIMARY STANDARD ADOPTED

The Committee believes that any calorimeter of the water

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heater type, when fitted with the accessories as provided in the recommendations of the Committee, that, when new, will test with the Primary Standard within two per cent. would be suitable for commercial use by any company.

From the information available, the Junkers, the Improved Sargent, or American Meter Company calorimeters are types of instruments which seem to be available for immediate use by the Companies, but they must in each case be equipped with the accessories as provided in the recommendations of the Committee. Any instrument of the above mentioned types must pass the prescribed test against the Primary Standard.

We believe that all makers of instruments of the water heater type prescribed should be encouraged to place their instruments in use.

Dr. Arthur H. Elliott, Ph. D., of New York, and J. B. Klumpp, M. E., of Philadelphia, met with the Committee; they entered into its discussions, aided in the determinations and join in the conclusions of the Committee.

W. R. ADDICKS, *Chairman,*
JAMES C. DELONG,
CHAS. H. STONE.

February 25, 1910.

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APPENDIX G.

REPRINT OF PLAN OF CALORIMETRIC INVESTIGATION AND EXPLANATION OF TEST AND REPORT FORMS

Tentatively adopted January 26, 1912, by the Joint Committee on Calorimetry, representing the Public Service Commission and Gas Corporations in the Second Public Service District, New York State.

INTRODUCTORY

On May 6, 1910, this Committee adopted certain Calorimetric Rules, Regulations and Specifications which were printed and a copy sent to each gas company operating in the second public service district in New York State. References made hereafter to "Calorimetric Rules, Regulations and Specifications" refer to this pamphlet. (See Appendix F, page 645).

A number of companies at once purchased and installed instruments in accordance with these specifications and started daily tests to determine the calorific value of their gas for the assistance of the Committee in its investigation.

As other companies are becoming interested in the investigation and are deciding to participate, it has become necessary to devise a definite plan for the investigation in order that the results obtained in different localities and under different conditions may be analyzed intelligently, and correct conclusions drawn therefrom.

The Committee is making a very comprehensive study of this entire subject and the plan formulated is therefore more elaborate than would be the case if merely the calorific values, without reference to operating conditions, were desired.

PLAN OF INVESTIGATION

The plan formulated comprises:

1. The making of daily calorimetric tests and the recording daily of certain works data. Form A is to be used for this purpose. (See insert opposite page 680).

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2. The submitting to the Committee monthly of the results of the daily tests and of monthly averages and totals of works data. Form B is to be used for this purpose. (See insert opposite page 680.)

3. The furnishing to the Committee of information regarding operating conditions, and apparatus and methods in use. A map or sketch with an accompanying letter of explanation and description is to be used for this purpose. (See page 675.)

EXPLANATION OF TEST AND REPORT FORMS.

FORM A.*

Apparatus in Use—

1. Each piece of apparatus will be given a designating letter or number (see page 675, paragraph 6f), and this letter or number may be used in noting the apparatus in use each day.

Send Out—

2. The maximum, minimum and average daily send out will be reported monthly and the figures will be obtained from these daily entries.

Works Started (First Blast On) at

Works Shut Down (Last Run Off) at—

Duration Intermediate Shut Down—

Total Works Operation—

3. The maximum, minimum and average hours per day of works operation will be reported monthly and the figures will be obtained from these daily entries.

Yield Per Lb. Coal—

Oil Per M.—

[1] See page 93.

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Generator Fuel Per M.—

4. In many instances it would be extremely difficult to determine these figures with any degree of accuracy on a daily run and in such cases it need not be attempted. On the other hand, if it is the practice to make these calculations, the figures should be entered for comparison with the monthly measurements. (See page 673, paragraph 5.)

Enricher Per 100 Lbs. Coal Carbonized—

5. The unit of "100 pounds coal carbonized" has been adopted as a fair basis for comparison.

The calculation should be made and the figures entered daily.

Kind of Enricher—

6. If cannel coal is used, the grade of this coal should be given, or if oil, the kind of oil. The practice in regard to this subject should be explained in considerable detail in the letter. (See page 621, paragraph 61.)

Duration of Charge—

7. The duration of charge each day should be noted so that the average daily duration of charge for the month can be obtained.

Mixed Gas

Coal Gas—per cent, Water Gas—per cent.

8. This is self-explanatory.

Time of Test—

9. A calorimetric test consists of one or more sets of readings taken continuously. On the form, three columns are

NOTE—The term "Corrected Gas" means that the quantity of gas, as measured by a meter, has been corrected to a standard of volume as represented when measured at a temperature of 60° Fahrenheit and a barometric pressure of 30 inches. The figure for corrected gas is obtained by multiplying the volume of uncorrected gas by a factor corresponding to the temperature and pressure at which the gas has been measured A table of "Correction Factors" is given on pages 676 and 677. This is copied with the permission of the author, from the table given in "Practical Testing of Gas and Gas Meters," by C. H. Stone.

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provided for three sets of readings. For
are headed Test 1, Test 2, Test 3. It shou
that the three sets of readings or "tests" ta
the results checked or averaged, constitute on
of starting this test should be given. (See Ca
Regulations and Specifications, Appendix F,
graph 15.) Should two or more tests be n
hours of the same day, a separate sheet should
test.

Barometer—

10. Refer to Calorimetric Rules, Regulati
cations, Appendix F, page 655, paragraph 2
The mercury column barometer specified
should have an adjustable zero and a vernier
the participating company is relying on bar
taken by the local weather bureau, the readin
nearest to the time of test should be used. C
ing should be taken as a part of the test.

Room Temperature—

11. The temperature of the room at the
should be stated in degrees Fahrenheit.

Candle-Power—

12. Two spaces are provided for candle-p
case two types of burners are used the resul
each can be entered separately. Spaces are
which the type of burner should be noted di
candle-power obtained with it. The result of
metric test only is to be noted on this form.
other photometric tests made during the da
garded so far as this investigation is concer
674, paragraph 14.)

Pressure

Meter Inlet— Burner Inlet—

13. These readings should be taken at the

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the test. (See Calorimetric Rules, Regulations and Specifications, Appendix F, page 659, paragraph 5.)

Minimum Temperature to Which Gas Has Been Subjected Before Test—

14. This temperature may be obtained by the use of an hygrometer. (See Proceedings American Gas Institute, Vol. I., 1906, pages 601 and 602.)

Rate of Combustion Per Hour—

15. See Calorimetric Rules, Regulations and Specifications, Appendix F, page 660, paragraph 9.

Exhaust Temperature—
Gas Temperature—

16. See Calorimetric Rules, Regulations and Specifications, Appendix F, page 661, paragraph 12.

Total Pressure Correction—

17. This means that the water pressure, at meter outlet, in inches, is calculated to inches of mercury and added to the barometric reading. It is desired to correct the pressure of the gas to 30 inches of mercury, from the combination of the barometric pressure and the inches of mercury calculated from the water pressure at which the gas is burned.

Correction Factor—

18. See Table, pages 676 and 677.

Uncorrected Gas Used in Test—
Corrected Gas Used in Test—

19. (See footnote, page 668.)

Weight, Water and Pail—
Weight, Pail Empty—
Weight, Water—

20. See Calorimetric Rules, Regulations and Specifications, Appendix F, page 656, paragraph 32; also Appendix F, page 661, paragraph 14.

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Temperature of Water—

21. Readings 1-20. See Calorimetric Rules, Regulations and Specifications, Appendix F, page 661, paragraph 14.

Average Temperature—

22. The average temperatures will, of course, be obtained by adding all the temperatures taken and dividing by the number of readings. Space is provided for this calculation.

Thermometer Correction—

23. This figure will be obtained from the calibration curve. See Calorimetric Rules, Regulations and Specifications, Appendix F, page 654, paragraph 24; also paragraphs 22, 23, 24 and 26, page 655.

Stem Correction—

24. See page 679.

Corrected Average Temperature—

25. This means the average temperature after the two corrections, thermometer and stem, have been applied.

Rise in Temperature—

26. The rise in temperature equals the corrected average outlet temperature minus the corrected average inlet temperature.

Calculation—

27. The general formula is:

$$\text{B. t. u. per cubic foot} = \frac{W \times T}{G + e}.$$

W = Weight of water.
T = Rise in temperature of water.
G = Corrected gas used in test.
e = Efficiency of instruments in tenths of 1 per cent. This figure is obtained from the most recent comparison of the instrument with the State standard.

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In the blank formula as stated on the form, the numerator contains the figure 1,000, so that the efficiency can be stated in whole numbers and decimals thus avoided.

A computer may be used in making the calculations after the blank formula has been filled out, but if this is done the correction for efficiency will have to be made separately. (See Calorimetric Rules, Regulations and Specifications, Appendix F, page 663, paragraph 19.)

Average = —— *B. t. u.*

28. The results obtained with the different sets of readings should check within 10 B. t. u's. Under such conditions the average of these results should be obtained and this figure will be the one transferred to the Monthly Summary, Form B. (See Calorimetric Rules, Regulations and Specifications, Appendix F, page 662, paragraph 15.)

FORM B.*

Coal Gas Made—
Carbureted Water Gas Made—
Mixed Gas Made—

1. This refers to the gas made during the calendar month. Whether the figures are for uncorrected or corrected gas should always be indicated.

Daily Send Out, Maximum—
Daily Send Out, Minimum—
Daily Send Out, Average—

2. These figures will be obtained from the entries for "Send Out" on Form A. (See insert opposite page 680.)

Gas Enriched (Yes or No)—
Gas Enriched (How)—

3. This subject will be reported on fully in the letter. (See page 678, paragraph 6-1) but should also be reported on, briefly, opposite these headings. (See also "Average Enricher" and "Kind of Enricher," page 673, paragraphs 7 and 8.)

[1] See page 94.

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Hours Per Day Works Operation, Maximum—
Hours Per Day Works Operation, Minimum—
Hours Per Day Works Operation, Average—

4. These figures will be obtained from the entries on Form A for "Total Works Operation."

Average Yield Per Lb. Coal—
Average Oil Per M.—
Average Generator Fuel Per M. —

5. These figures should be based on measurements of the coal, oil or fuel on hand at the beginning and end of the month and not on the averages of the entries on Form A. (See page 668, paragraph 4.)

Kind of Coal—

6. The information desired is the commercial name of the coal used and the mine from which it comes, if this is known.

Average Enricher Per 100 Lbs. Coal Carbonized—

7. This figure will be the average of the daily entries on Form A. (Insert opposite page 680.)

Kind of Enricher—

8. (See page 668, paragraph 6.)

Average Duration of Charge—

9. This figure will be the average of the daily entries on Form A. (Insert opposite page 680.)

Kind of Oil—

10. This entry should give the "kind of oil," the district where the oil is produced, if definitely known, and the specific gravity in degrees Beaumé, if this figure is available. If the companies have any distillation test figures, they should be given.

Kind of Fuel—

11. This entry should state whether coal or coke is used, and if the latter, whether retort or oven.

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Mixed Gas.

Coal Gas — per cent., Water Gas — per cent.

12. These figures will be the average of the corresponding entries on Form A. (See insert opp. page 680.)

Calorific Values—

13. As explained, page 668, paragraph 9, a test consists of one, two or three sets of readings. This form provides space for only one test per day at works and one at office, or some other location. If more tests are made, additional sheets should be used.

The figure to be entered will be taken from Form A, (See insert opp. page 680.) "Average B. t. u.," but the nearest whole number should be given and decimals eliminated.

Candle-Power—

14. The candle-power figures to be entered should be taken from Form A, (see insert opp. page 680), "Candle Power." The entry should *not* represent the average of all photometric tests made during the day, but should be the candle-power at the time the calorimetric test is made. The candle-power should be stated with only one decimal.

Minimum Temperature Gas—

15. As explained in the note on the form, this refers to the minimum temperature to which the gas has been subjected before test. The figures should be taken from the corresponding entries on Form A. (See insert opp. page 680.)

Temperature of Atmosphere—

16. The maximum and minimum temperature of atmosphere should be stated in degrees Fahrenheit. As no space is left for them on Form A they may be entered daily on Form B. (See insert opp. page 680.)

Maximum—

Minimum—

17. Refers to figures in columns above.

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Note—

18. When calorimetric or photometric tests are made at both works and office or some other location, the tests at the two places should be made simultaneously.

MAP AND LETTER.

1. A detailed map, or if this is not possible, a sketch, on paper 8½ inches by 14 inches should be submitted.

2. This map or sketch should show the relative location of the works and holders and should indicate the points at which the tests are made.

3. If these tests are made at a distance from the works, this distance following the course taken by the gas should be accurately shown. Also if any exposed bridges have been crossed, or if the line runs under water, these points should be made clear.

4. Such map or sketch will be asked for but once unless changes are made, and it should therefore contain information regarding all matters which are liable to affect the results obtained in the tests.

5. The map or sketch should be accompanied by a letter, also on paper 8½ inches by 14 inches, containing a general description of the apparatus and methods employed.

6. Such letter should state:

(a) Kind of gas made.
(b) Manufacturing capacity of plant, giving figures for coal gas and water gas separately.
(c) Gas holder capacity at plant.
(d) Gas holder capacity outlying.
(e) Holders housed or exposed.
(f) List of generator apparatus with type and capacity of each piece of apparatus. The different pieces of apparatus may be designated by a letter or number for future reference.
(g) Type and make of calorimeter.
(h) Type and make of photometer.

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CORRECTION FACTORS FOR TEMPERATURE AND BAROMETRIC PRESSURE FROM PRACTICAL TESTING OF GAS AND GAS METERS.—*By C. H. Stone.*

	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.
107	.816	.820	.823	.826	.829	.832	.835	.838	.841	.844	.847	.851	.854	.857	.860	.864	.867	.870	.874	.8
106	.820	.823	.826	.829	.832	.835	.838	.841	.844	.847	.851	.854	.857	.860	.863	.867	.870	.874	.878	.8
105	.823	.827	.830	.833	.836	.839	.842	.845	.848	.851	.855	.858	.861	.864	.867	.871	.874	.878	.881	.8
104	.827	.830	.833	.836	.839	.842	.845	.848	.851	.854	.858	.861	.864	.867	.871	.874	.878	.881	.884	.8
103	.830	.834	.837	.840	.843	.847	.849	.852	.855	.858	.862	.865	.868	.871	.874	.878	.881	.885	.888	.8
102	.834	.837	.840	.843	.847	.850	.853	.856	.859	.862	.865	.868	.871	.874	.878	.881	.885	.888	.891	.8
101	.837	.840	.843	.846	.850	.853	.856	.859	.862	.865	.868	.872	.875	.878	.882	.885	.888	.891	.895	.8
100	.840	.843	.846	.849	.853	.856	.859	.862	.865	.868	.872	.875	.878	.881	.885	.888	.891	.895	.898	.9
99	.844	.847	.850	.853	.857	.860	.863	.866	.869	.872	.876	.879	.882	.885	.889	.892	.895	.898	.902	.9
98	.847	.850	.853	.856	.860	.863	.866	.869	.872	.875	.879	.882	.885	.888	.892	.895	.898	.902	.905	.9
97	.850	.853	.856	.859	.863	.866	.870	.873	.876	.879	.882	.885	.888	.891	.894	.898	.901	.905	.908	.9
96	.854	.857	.860	.863	.867	.870	.873	.876	.879	.882	.886	.889	.892	.895	.898	.901	.904	.908	.911	.9
95	.857	.860	.863	.866	.870	.873	.876	.879	.882	.885	.889	.892	.895	.898	.901	.904	.908	.911	.914	.9
94	.860	.863	.866	.869	.873	.876	.879	.882	.885	.888	.892	.895	.898	.901	.904	.907	.911	.914	.918	.9
93	.863	.866	.869	.872	.876	.879	.883	.886	.889	.891	.895	.898	.901	.904	.907	.910	.914	.918	.921	.9
92	.866	.869	.872	.875	.879	.882	.885	.889	.892	.894	.898	.902	.904	.907	.910	.914	.917	.921	.924	.9
91	.869	.872	.875	.879	.882	.885	.889	.892	.895	.898	.902	.905	.908	.911	.914	.917	.921	.924	.928	.9
90	.872	.875	.878	.881	.885	.888	.892	.895	.898	.901	.905	.908	.911	.914	.917	.920	.924	.927	.931	.9
89	.875	.878	.882	.885	.889	.892	.895	.898	.901	.904	.907	.910	.914	.917	.920	.923	.927	.931	.934	.9
88	.878	.881	.885	.888	.892	.895	.898	.901	.904	.907	.910	.913	.917	.920	.923	.926	.930	.934	.937	.9
87	.881	.884	.888	.891	.895	.898	.901	.904	.907	.910	.913	.916	.920	.923	.926	.929	.933	.937	.940	.9
86	.884	.887	.890	.894	.898	.901	.904	.907	.910	.913	.916	.919	.923	.926	.929	.932	.936	.940	.943	.9
85	.887	.890	.893	.896	.900	.903	.906	.909	.913	.916	.919	.922	.926	.929	.932	.936	.939	.943	.946	.9
84	.889	.893	.896	.899	.903	.906	.909	.912	.915	.919	.922	.925	.928	.932	.935	.939	.942	.946	.949	.9
83	.892	.895	.899	.902	.906	.909	.912	.915	.918	.921	.924	.928	.931	.935	.938	.942	.945	.949	.952	.9
82	.895	.898	.901	.905	.908	.911	.914	.918	.921	.924	.927	.931	.934	.937	.941	.945	.948	.951	.954	.9
81	.898	.901	.905	.908	.911	.914	.917	.921	.924	.927	.930	.934	.937	.940	.944	.948	.951	.954	.957	.9
80	.901	.904	.907	.910	.914	.917	.920	.923	.927	.930	.933	.937	.940	.943	.946	.950	.954	.957	.960	.9
79	.904	.907	.910	.914	.917	.920	.923	.626	.930	.933	.936	.939	.943	.946	.949	.953	.956	.960	.963	.9
78	.906	.909	.913	.916	.919	.923	.926	.929	.932	.936	.939	.942	.946	.949	.952	.956	.959	.962	.966	.9
77	.909	.912	.915	.919	.922	.925	.928	.931	.935	.938	.942	.945	.948	.951	.955	.958	.962	.965	.968	.9
76	.911	.915	.918	.921	.925	.928	.931	.935	.938	.941	.944	.948	.951	.954	.958	.961	.964	.968	.971	.9

75	.914	.917	.921	.924	.928	.931	.934	.937	.940	.943	.947	.950	.954	.957	.960	.963	.967	.971	.974	.978
74	.917	.920	.924	.927	.930	.933	.937	.940	.943	.947	.950	.953	.957	.960	.963	.966	.970	.973	.977	.980
73	.920	.923	.926	.930	.933	.936	.940	.943	.946	.949	.953	.956	.960	.963	.966	.969	.972	.976	.980	.983
72	.922	.925	.929	.932	.935	.939	.942	.945	.949	.952	.955	.959	.962	.965	.968	.972	.975	.979	.982	.986
71	.925	.928	.931	.935	.938	.941	.945	.948	.951	.954	.958	.961	.965	.968	.971	.975	.978	.981	.985	.989
70	.927	.931	.934	.937	.941	.944	.947	.950	.954	.957	.960	.964	.967	.970	.974	.977	.980	.984	.988	.991
69	.930	.933	.937	.940	.944	.947	.950	.953	.957	.960	.963	.967	.970	.973	.977	.980	.983	.987	.990	.994
68	.932	.936	.939	.942	.946	.949	.952	.956	.959	.962	.966	.969	.972	.976	.979	.983	.986	.989	.993	.997
67	.935	.938	.942	.945	.949	.952	.955	.959	.962	.965	.968	.972	.975	.979	.982	.985	.989	.992	.996	1.000
66	.938	.941	.944	.948	.951	.954	.958	.961	.964	.968	.971	.974	.978	.981	.985	.988	.992	.995	.998	1.002
65	.941	.944	.947	.950	.954	.957	.960	.963	.967	.970	.973	.977	.980	.984	.987	.991	.994	.997	1.001	1.005
64	.943	.946	.949	.953	.956	.959	.963	.966	.969	.973	.976	.980	.983	.986	.990	.994	.997	1.000	1.004	1.008
63	.945	.949	.952	.955	.959	.962	.965	.969	.972	.975	.979	.982	.985	.989	.993	.996	1.000	1.003	1.006	1.010
62	.947	.951	.954	.958	.961	.964	.968	.971	.975	.978	.981	.985	.988	.991	.995	.999	1.002	1.005	1.009	1.013
61	.950	.954	.957	.961	.964	.967	.971	.974	.977	.981	.984	.987	.991	.994	.998	1.001	1.005	1.008	1.011	1.015
60	.952	.956	.959	.963	.966	.969	.973	.976	.980	.983	.986	.990	.993	.997	1.000	1.004	1.007	1.010	1.014	1.017
59	.955	.959	.962	.966	.969	.972	.976	.979	.983	.986	.989	.992	.995	.999	1.003	1.006	1.010	1.013	1.016	1.020
58	.957	.961	.964	.968	.971	.975	.978	.981	.985	.988	.992	.995	.998	1.002	1.005	1.009	1.012	1.016	1.019	1.023
57	.960	.963	.967	.970	.974	.977	.980	.984	.988	.991	.994	.997	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025
56	.962	.966	.969	.973	.976	.979	.982	.986	.990	.993	.996	1.000	1.003	1.007	1.010	1.014	1.017	1.021	1.024	1.028
55	.965	.968	.992	.975	.979	.982	.985	.989	.993	.996	.999	1.002	1.006	1.009	1.013	1.016	1.020	1.023	1.027	1.030
54	.967	.970	.974	.977	.981	.984	.988	.991	.995	.998	1.001	1.005	1.008	1.012	1.015	1.019	1.022	1.026	1.029	1.033
53	.969	.973	.976	.980	.983	.986	.990	.993	.997	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025	1.028	1.031	1.035
52	.971	.975	.978	.982	.985	.989	.992	.996	.999	1.003	1.006	1.010	1.013	1.017	1.020	1.024	1.027	1.031	1.034	1.038
51	.974	.977	.981	.984	.988	.991	.995	.998	1.002	1.005	1.009	1.012	1.016	1.019	1.023	1.026	1.030	1.033	1.037	1.040
50	.976	.980	.983	.987	.990	.994	.997	1.001	1.004	1.008	1.011	1.015	1.018	1.022	1.025	1.029	1.032	1.036	1.039	1.043
49																				

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(i) Type of standard and burner used in photometer test.

(j) General description of the methods used and conditions under which the tests are made. For example, such a description might be that the calorific and candle-power values are taken at office located at works, that the gas is taken from inlet of the street governor and has been in the storage holder, and that, as this holder is exposed, the probabilities are that the gas has been subjected to the extreme temperatures of the atmosphere.

Or, for another example, that the tests are made at the company's office, located a mile from the works, that the gas is taken from the house piping or that it is taken from an individual service; if this service is any way exposed to the temperature of the atmosphere, it should be mentioned; that the gas has passed over an exposed bridge as shown on the map, etc.

(k) Concise statement of how the gas is stored and exposed before it is delivered to the street mains.

(l) Concise statement of methods employed in enriching.

WM. MCCELLAN, *Chairman*,
A. H. ELLIOTT,
J. B. KLUMPP,
C. F. LEONARD,
C. H. STONE.

January 26, 1912.

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(NAME OF COMPANY)

SUMMARY MONTH OF _____

GAS MAKING RECORDS

Coal Gas Made.....cu. ft. { Uncorrected / Corrected

Carburetted Water Gas Made ..... " { Uncorrected / Corrected

Mixed Gas Made..... " { Uncorrected / Corrected

Gas enriched (yes or no) .....

" " (how) .....

.....

Daily Send Out, Maximum .....cu. ft { Uncorrected / Corrected

" " " Minimum ..... " { Uncorrected / Corrected

" " " Average..... " { Uncorrected / Corrected

Hours per day works operation, maximum.....hours

" " " " minimum..... "

" " " " average..... "

COAL GAS

Ave. yield per lb. coal uncorrected gas.....cu. ft.

" " " corrected gas..... "

Kind of coal.....

Ave. enricher per 100 lbs. coal carbonized.....lbs.....gals.

Kind of enricher .....

Ave. duration of charge.....

WATER GAS

Ave. oil per M uncorrected gas..... .....gals.

" " corrected gas..... "

Kind of oil.....

Ave. generator fuel per M uncorrected gas.....lbs.

" " " " corrected gas..... "

Kind of fuel .....

MIXED GAS

Coal Gas.....% Water Gas.....%

RESULTS OF TESTS

DAY	AT WORKS					AT					TEMP. OF ATMOSPHERE	
	Min. Temp. Gas*	B. T. u. ?.	Readings	C. P.	Readings	Min. Temp. Gas*	B. T. u.	Readings	C. P.	Readings	Maximum	Minimum
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
Maximum												
Minimum												
Average												

*MINIMUM TEMPERATURE TO WHICH GAS HAS BEEN SUBJECTED BEFORE TEST

NOTE:—For explanation of use of this form see "Plan of Calorimetric Investigation and Explanation of Test and Report Forms," Joint Committee on Calorimetry, Jan. 26, 1912

Remarks .....

.....

Signed.....Approved.....

The actual size of this form is 8½" x 11".

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In general, all corrections are determined
sion, *i. e.*, for the condition where both bulb
themometer are at the same temperature.
stem is emergent into space, either hotter o
temperature of the bulb, a stem correction
to the observed reading.

This so-called stem correction may be cc
number of degrees emergent and the differen
between the bath and the space above it a
amount to more than 68° F. for measure
a mercury thermometer at 752° F.

For the glass of which this thermometer
correction may be computed from the follow

Stem correction=0.000088 x n (T°—t°)
n=number of degrees emergent from th
T=temperature of bath.
t=mean temperature of the emergent st

The mean temperature, t°, may be approxi
by means of a small auxiliary thermometer
the emergent stem, or by surrounding the la
water jacket and taking the temperature of
the auxiliary thermometer, or, more accura
suggested by Guillaume, by exposing an exa
and capillary mercury thread beside the em
thus measuring its mean temperature.

This is also conveniently carried out with th
mometer" (Fadenthermometer) of Mahlke, i
pansion of the mercury in the capillary tube
ured on a still finer capillary stem.

Example—

Suppose that the observed temperature w
thermometer was immersed to the 32° mark
that 53° of the mercury column projected out

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the mean temperature of the emergent column was found to be 70° F., then—

$$\text{Stem correction} = 0.000088 \times 53\ (85-70).$$
$$= 0.07°$$

As the stem was at a lower temperature than the bulb, the thermometer read too low, so that this correction must be added to the observed reading to find the reading corresponding to total immersion, *i. e.*, 85.00° + 0.07° = 85.07° F.

This correction must be considered in addition to any correction shown by the certificate accompanying the thermometer.

For further information in regard to this subject see "The Correction for Emergent Stem of the Mercurial Thermometer," published by the U. S. Bureau of Standards as Reprint No. 170.

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In Memi

AUGUST 31, 19

HENRY EASTLAND A
Died

W. A. BIXBY,
Die

JOHN A. COFFIN,
Died

DAVID DOUGLAS,
Di

RUFUS E. HOLMES,
Di

GUSTAVUS A. HYDE,
Died Nov

P. S. MARQUIS,
Died Nov

FREDERICK J. MAYEI
Died Sep

KERR MURRAY MITC
Died

CHARLES W. MORSE,
Die

WILLIAM T. ROBINSO
Died

THOMAS V. RUTTER,
Died Dec

DR. F. SCHNIEWIND,
Died

COLIN C. SIMPSON, Sr.,
Die

WILLIAM STEINWEDE
Died Oc

CHARLES F. TERHUN
Died A

CHRISTIAN EDGAR TI
Died

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HENRY EASTLAKE ADAMS.

Mr. Adams died suddenly March 12th, 1913, in Stockton, California. Mr. Adams entered the gas business upon leaving the Stockton High School in 1882 under his father and upon the death of the latter in 1893 succeeded him as Superintendent and later became Manager of the Stockton Gas, Light & Heat Company, which position he retained until ownership of the corporation went into other hands when he entered the service of the Oro (California) Electric Company which position he held at the time of his death.

Mr. Adams was a charter member of the Pacific Coast Gas Association, its President at the time of his death, and a charter member of the American Gas Institute.

He was a man of marked ability and a personality that commanded respect.

JOHN A. COFFIN.

Mr. Coffin was one of the early members of the New England Association of Gas Engineers having become a member in 1883 and was a Past President of that Association, he was a charter member of the Guild of Gas Managers, became a member of the American Gas Light Association in 1886 and was a charter member of the American Gas Institute.

Mr. Coffin was in his 60th year when he died at his home in Gloucester, Mass., where he successfully managed the Gas Company for a great many years.

He was always a popular citizen and was beloved by a large circle of friends. Of a genial and pleasant personality he became prominent in gas circles and was particularly active in New England gas matters.

DAVID DOUGLAS.

Mr. Douglas, President and General Manager of the Eau Claire Gas Light Company, Eau Claire, Wis., died April 30th, 1913, in his 68th year, having been a prominent member of the gas fraternity for over forty years.

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Mr. Douglas died at his home in Eau Claire, and had been an active member of the American Gas Institute since 1910.

In his death, May 3rd, Eau Claire lost one of its most public spirited citizens. Originally with the Minneapolis (Minn.) Gas Company, in 1894 he came to Eau Claire, and organized the Eau Claire Gas Light Company, of which corporation he was President at the time of his death. He was also President of the Manitowoc (Wis.) Gas Company, a corporation that virtually owes its commencing to his activity. He was prominent in Association work, especially in the Western Gas Association. He was a Director and a principal share holder in the Brunett Falls Manufacturing Company at Cornell, Wis., and was also interested in many local enterprises in the State. He was quite active in politics, having served as Mayor of Eau Claire for several terms, represented the Eau Claire district in the State Legislature, and was always prominent in matters pertaining to civic advancement. He was for years a warden of Christ Episcopal Church.

RUFUS E. HOLMES.

Mr. Holmes, President of the Winsted Gas Company, Winsted, Conn., died at his home in that city, May 5th, 1913.

Mr. Holmes became a member of the American Gas Light Association in 1899 and was a charter member of the American Gas Institute. He became a member of the New England Association of Gas Engineers in 1903.

Mr. Holmes was a prominent citizen of Winsted and a man of large influence in civic affairs.

GUSTAVUS A. HYDE.

Mr. Hyde was one of the veterans in the gas business, born January 15th, 1826, he was a civil engineer in railroad building until 1885 when he became Engineer of the City of Cleveland, Ohio, and in February, 1859, was appointed Engineer

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of the Cleveland Gas Light & Coke Company, which position he held 48 years when he retired, March 1st, 1907. He planned and built both of the present gas works, as well as remodelling several other gas works in Ohio.

Mr. Hyde became a member of the Western Gas Association in 1880, the American Gas Light Association 1887, the Ohio Gas Light Association 1890 and was elected a Life Member of the American Gas Institute in 1909.

His death at his home, November 26th, 1913, closed a long, useful and honorable life, full of good deeds and valuable service.

P. S. MARQUIS.

Mr. Marquis was connected with the Barrett Manufacturing Company, St. Louis, Mo., and died November 12th, 1912, at his home in that city. Mr. Marquis became a member of the American Gas Institute in 1906.

FREDERICK J. MAYER.

Mr. Mayer was born at Bremerhaven, Germany, July 4th, 1853. He received his early education at University of Stuttgart, Germany, and came to this country in 1870 after the Franco-Prussian War, in which he saw active service. Being an engineer, he engaged with the Bartlett Hayward Co., of Baltimore, Md., as draftsman and while with them, up to 1906 as Chief Engineer he designed, erected and operated many of the large gas plants constructed by that Company. In 1906 Mr. Mayer severed his connection with the Bartlett Hayward Co., organized and established the Didier-March Company in the United States, taking the position of General Manager.

Having made a life study of the carbonization of coal for metallurgical and domestic purposes, to him must be credited the establishing of some of the best foreign apparatus in the United States for the carbonization of coal.

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Mr. Mayer invented many improvements for the manufacture of illuminating gas.

At the time of his death Mr. Mayer was 59 years old, an ardent and tireless worker, well known in the United States and abroad, a member of the American Gas Institute, the American Society of Mechanical Engineers, the Illuminating Engineering Society, Chemists Club, American Peat Society, German Club and many other social and Technical Organizations.

KERR MURRAY MITCHELL.

Mr. Mitchell, General Manager of the St. Joseph Gas Company, St. Joseph, Mo., died at his home in that city April 18th, 1913.

Mr. Mitchell was born in Buffalo, N. Y., just two weeks after his parents arrived in this country from Edinburgh, Scotland, their native city. Stern necessity obliged him, at the early age of 12, to seek work and he entered the employ of Kerr Murray, the man for whom he was named as an apprentice to learn the construction trade. So rapidly did he advance that in his sixteenth year he was entrusted with the supervision of the building of the plant at Windsor, Ontario, where after completing the plant he remained Manager until 1878.

While engaged in this work he became acquainted with Mr. C. H. Nash, then connected with the Detroit Gas Company, who had secured a franchise for a gas works at St. Joseph, Mo., and who had formed such a favorable opinion of Mr. Mitchell's qualifications that he had him construct the plant upon completion of which he became General Manager which position he held until his death. He rose to such favorable prominence in that city that at his death he was in many ways its most prominent citizen, and his funeral was a remarkable tribute to his memory.

He joined the Western Gas Association in 1899 and was elected its President in 1906. He united with the American

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Gas Light Association in 1889 and was a charter member of the American Gas Institute, he was also a member and past President of the Natural Gas Association.

CHARLES W. MORSE.

Mr. Morse, President and General Manager of the Amesburg Gas Co., Haverhill, Mass., died in Gainesville, Florida, where he had gone in hope of regaining his health.

Mr. Morse at one time owned the gas plants at Marlboro and Quincy, Mass., and was largely interested in gas properties at Rochester, N. H., Amesbury and Salisbury, Mass., and Gainesville, Florida.

He was born in Haverhill in 1857 and at the time of his death was in the lighting business in that city.

He became a member of the American Gas Light Association in 1902 and was a charter member of the American Gas Institute in 1906.

WILLIAM T. ROBINSON.

Mr. Robinson at the time of his death March 25th, 1913, was Secretary and Treasurer of the American Gas Company, Philadelphia, Pa., which position he had held for several years.

Mr. Robinson was at one time General Manager of the Pennsylvania Warehousing & Safe Deposit Company and President of the Philadelphia Warehousing & Cold Storage Company, and was at the time of his death Treasurer of the Philadelphia Board of Trade.

He was in his 53rd year, was a graduate of the University of Pennsylvania, a member of the Zeta Psi Fraternity and the Sons of the Revolution.

He became a member of the American Gas Institute in 1910.

THOMAS V. RUTTER.

Mr. Rutter of the firm of Turner & Rutter, Leather Dealers, an Associate member, died in New York City, December 19th, 1912.

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Mr. Rutter united with the American Gas Light Association in 1904 and was a charter member of the American Gas Institute.

DR. F. W. C. SCHNIEWIND.

Dr. Schniewind, whose death occurred at his home in Englewood, N. J., March 12th, 1913, was a man of international reputation, a man of rare accomplishments, and was a distinct loss to the gas fraternity.

Born October 23rd, 1861, a chemist having studied at Charlottenburg, Munich, and Heidelberg from the latter receiving the degree of Ph. D., he came to this country in 1890 and began work in Cleveland, O., conducting an analytical laboratory.

He became interested in a by-product coke oven process as the American representative of Dr. C. Otto & Co., of Dalhausen, Germany, erecting a plant at Glassport, Pa., which he conducted as chemist and Manager.

His success at this point was such that he could clearly foresee the importance of the new departure and the tremendous future possibilities which resulted in his enlisting capitalists and the organization of the United Coke and Gas Company, and the building of the 400 oven plant at Everett, Mass.

At the time of his death he was President and sole owner of the German-American Coke and Gas Company, and its subsidiary companies, the United Coke and Gas Co., and the American Coke and Gas Construction Company, as well as President of the newly organized Schniewind Coke Oven Company.

He was a member of the American Gas Light Association 1896, a charter member of the American Gas Institute, the National Commercial Gas Association, the Illuminating Engineering Society, the Franklin Institute, and a large number of other technical societies and clubs.

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COLIN C. SIMPSON, SR.

Mr. Simpson died April 8th, 1913, at his home in Montclair, N. J. He was educated at a private school in England; Technical High School, Gratz, Austria; and Naval Academy, Trieste, Austria. On completion of his course there, he spent the required two years at sea, on sailing vessels.

On his return from sea he secured employment with an English contracting firm in Vienna laying water mains in that city. He came to the United States in 1880 and entered the employ of the Municipal Lighting Company at its 26th Street and Fourth Avenue office and later was transferred to the 99th Street station of the Knickerbocker Gas Company, being a portion of the time in the clerical department and a portion of the time in the engineering department. In 1882 he was placed in charge of mains of the Municipal and Knickerbocker Gas Companies. At the time of the consolidation in 1884, he was made district superintendent of mains of the Consolidated Gas Company of New York.

In 1889 he became General Superintendent of Mains of the Consolidated Gas Company and in 1902 was appointed Assistant Secretary of the Consolidated Gas Company of New York, both of which offices he continued to fill until his death.

He was a leading exponent of absolute safety with respect to gas mains and designed and had adopted the system of bypassing of all gas mains now in general use during the construction of subways.

He was a member of the American Gas Light Association, 1903, charter member of the American Gas Institute, American Society of Mechanical Engineers, Engineers Club, Society of Gas Engineering and the Illuminating Engineering Society.

CAPT. WILLIAM STEINWEDELL.

Capt. William Steinwedell, an old resident and prominent citizen of Quincy, Ill., died at his residence in that city, October 18, 1912, in his eighty fifth year having spent sixty years

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of the time as a resident of Quincy, occupying a commanding position in its commercial and financial affairs.

At the breaking out of the rebellion, Capt. Steinwedell organized a local military company, which did valuable service in that locality, without compensation and without expense to the government. He secured the money in the banks at La Grange and Canton and delivered it to the sub-treasury at St. Louis, by order of Major General Fremont; furnished the escort for 20,000 stands of arms for Iowa troops from Quincy to Keokuk; relieved the Sixtieth Illinois regiment when it was besieged by confederates at Monroe City, Mo., and was in constant service for nearly four years. He was president of the Board of trustees of the Soldiers' Home from 1894 until a press of private business caused him to resign in the fall of 1897. For over twenty years he was President of the Quincy Gas Company and was a stockholder in various banks and industrial companies.

He was a member of the American Gas Light Association 1887, and a charter member of the American Gas Institute.

CHARLES F. TERHUNE.

Mr. Terhune, Vice-President of the Wm. M. Crane Company, and Vice-President of the New Bern (N. C.) Gas Company, died in New York City, August 10th, 1913.

Mr. Terhune was best known as a member of the Wm. M. Crane Company, his long and honorable connection with that firm giving him an extensive acquaintance in the gas appliance division of the gas industry. He was a member of the Western Gas Association (1900), the Ohio Gas Light Association (1900), the American Gas Light Association (1901), and a charter member of the American Gas Institute. He was also a member of the National Commercial Gas Association.

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CHRISTIAN EDGAR TITZEL.

Mr. Titzel, General Manager of the Conestoga Traction Company, and Superintendent of the Lancaster Gas Light & Fuel Company, Lancaster, Pa., died at the early age of 39 years at his home in Lancaster, March 30th, 1913.

Mr. Titzel although only 39 years old had been in the employ of gas and electric companies for twenty-four years and was a man of large experience, great executive ability and a man of large promise and was a distinct loss to the gas industry.

Mr. Titzel became a member of the American Gas Light Association in 1902 and was a charter member of the American Gas Institute.

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CONSTITUTION AND BY-LAWS

OF THE

AMERICAN GAS INSTITUTE

CONSTITUTION

NAME.

SECTION 1. The name of this association shall be the AMERICAN GAS INSTITUTE.

OBJECTS.

SECTION 2. The objects of this Institute are to amalgamate into one body the American Gas Light Association, the Ohio Gas Light Association, and the Western Gas Association, and to facilitate co-operation between the various state and district associations that now exist, or may hereafter be formed within the territory covered, and to secure thereby the more rapid promotion and advancement of scientific and practical knowledge in all matters relating to the construction and management of gas works and the manufacture, distribution and consumption of gas; the firmer establishment and maintenance of a spirit of fraternity between those interested in the gas business by affording opportunity for social intercourse and friendly interchange of information and ideas; the inducement and extension of more cordial and friendly relations between gas companies and consumers of gas based upon their mutual interests, and the education of employees of gas companies to enable them to better perform their duties. Also to take over such property and assets of the associations named as may be legally invested in the Institute.

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MEMBERS.

SECTION 3. The membership of the Institute shall consist of Honorary Members, Active Members, Junior Members and Associate Members. Honorary Members, Junior Members and Associate Members shall not be entitled to vote nor to hold office, but shall be entitled to all the other privileges of membership.

SECTION 4. Honorary Members shall be persons whose scientific or practical knowledge in matters relating to the gas industry, and whose efforts and interests in that behalf shall recommend them to the Institute.

SECTION 5. To be eligible to Active Membership, a person must be at least 26 years of age, and be an officer or other employee of a Gas Company; or a Consulting Gas Engineer, or an employee of a Consulting Gas Engineer. He must be competent to act efficiently as the Manager of a department of a Gas Company's business and must have his chief interest in the gas business directly connected with the manufacture, sale, or utilization of gas, and not the manufacture or sale of apparatus or appliances used by Gas Companies.

SECTION 6. To be eligible as a Junior Member, a person must be over 20 years of age and be in the employ of a Gas Company, or of a Consulting Gas Engineer, and must be qualified either by experience or education to hold a responsible position under such employers.

SECTION 7. To be eligible as an Associate Member, a person must be engaged in a pursuit which constitutes a branch of gas engineering, or be otherwise qualified to assist in promoting the objects of the Institute.

SECTION 8. Charter Members shall be such of the present membership of the American, Ohio, or Western Gas Association as shall be certified by the officers of the same to the Directors of the Institute as qualified respectively for Active, Junior or Associate Membership, provided that to become a

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Charter Member, it shall be necessary for each person so certified to make application to the Directors of the Institute within a period of sixty days after notice has been sent him of the formation of the Institute.

ELECTION OF NEW MEMBERS.

SECTION 9. Honorary Members shall be proposed by the Directors to the members of the Institute by mailed notifications immediately after any annual meeting, and shall be voted upon by letter ballot at the time of the regular September ballot next following.

SECTION 10. Every application for either Active, Junior or Associate Membership shall be made to the Secretary in writing upon a form approved by the Directors, upon which shall be set forth as the grounds of the application a complete account of the qualifications and experience of the applicant and his agreement to conform, if elected, to the Constitution, By-Laws and Rules of the Institute, and shall be endorsed by at least two Active Members to whom the applicant is personally known. The Secretary shall submit each application to the Directors, who shall consider and act upon it and assign the applicant to the grade of membership to which, in their judgment, his qualifications entitle him. The name of each candidate thus approved by the Directors shall, unless objection is made by the applicant, be submitted to the voting membership for election by means of a letter ballot.

SECTION 11. It shall be competent for any Junior or Associate Member to apply for transfer to another grade of membership. The application for such transfer shall be made in the same manner as in the case of a new applicant.

SECTION 12. Election to membership shall be by a sealed letter ballot, as the By-Laws shall provide. Adverse votes to the number of 2 per cent. of the votes cast shall be required to defeat the election of an applicant for any grade of membership. The Directors may, in their discretion, order a second

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ballot upon a defeated applicant, in which
to the number of 4 per cent. of the votes ca
to defeat the election.

SECTION 13. Any person elected to th
Honorary Members, must subscribe to th
pay to the Treasurer the initiation fee ar
for his grade of membership before he car
rights and privileges, or can receive a cert
ship. If this rquirement is not complie
months of the notification of the election
be deemed to have declined the election an
be void.

INITIATION FEES AND D

SECTION 14. The initiation fee for m
grade shall be as follows:

For Active Members .....
For Associate Members .....
For Junior Members .....

The initiation fees shall not include the
rent year in which the applicant is elected.

SECTION 15. A Junior Member, on prom
grade of membership, shall pay an additio
except that Charter Junior Members shall
pay such additional fee. No person shall re
bership for more than two years after beco
Active Membership.

SECTION 16. The annual dues, payable
membership in each grade shall be as follow

For Active Members .....
For Associate Members .....
For Junior Members .....

SECTION 17. The Directors may in their
any Active or Associate Member to becom

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in the same grade by the payment in one sum of an amount sufficient to purchase from a reputable life insurance company an annuity on the life of a person of the age of the applicant equal to the annual dues in his grade of membership. Such life member shall not be liable thereafter for annual dues. Life Members of the associations dissolving shall only be required to pay the difference, if any, between the sum computed as above and that already paid for their present Life Membership.

SECTION 18. The Directors shall have power by letter ballot to admit to Life Membership, without payment of a Life Membership fee, any person who for a long term of years has been an Active or an Associate Member, when, for special reasons, such an action would, in their judgment, promote the best interests of the Institute. Notice that such action as proposed shall have been given at a previous meeting of the Directors and one dissenting vote shall defeat the proposed action.

SUSPENSIONS AND EXPULSIONS.

SECTION 19. A member whose dues for a year completely expired are not paid, shall not be entitled to vote, nor to participate in the deliberations of the Institute, nor to receive a copy of the Proceedings. Any member whose dues shall remain unpaid for a term of three years may be dropped from the roll of membership by a vote of the Directors. A member dropped for non-payment of dues may upon paying the amount he owes the Institute, be reinstated at the option of the Directors.

SECTION 20. The Directors may refuse to receive the dues of any member of any grade who shall have been adjudged by them to have violated the Constitution or By-Laws of the Institute, or who, in their opinion, shall have been guility of conduct rendering him unfit to continue in its membership, and such person may be expelled from the Institute upon a recommendation to that effect made by the Directors at any gen-

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eral meeting of the Institute. The vote upon expulsion shall be by ballot and shall require two-thirds of the votes cast for its adoption.

SECTION 21. The Directors may transfer any member from his then present to any lower grade of membership. They may also refuse to receive the dues of any member who is no longer eligible to any grade. No transfer of grade shall be made, or refusal to accept dues recorded, except upon notice from the Secretary, whose duty it shall be to give such notice, that said member is no longer eligible for membership in his then present grade, and that said member has for a period of ninety days after notification of such non-eligibility, failed to apply for transfer. The vote in each case shall be by ballot, and shall require two-thirds of the votes cast for its adoption.

MANAGEMENT.

SECTION 22. The affairs of the Institute shall be managed by the Directors, subject to the control of the general meeting.

SECTION 23. The Board of Directors shall consist of the President, the two Vice-Presidents, the Secretary, the Treasurer, the Junior Past-President, and until changed as hereinafter provided for, ten Active Members of the Institute. Five members shall constitute a quorum for the transaction of business. If arrangements are made for co-operation between the Institute and district and state gas associations, as hereinafter provided for, the number of members of the Board elected from the Active Members of the Institute shall be increased from time to time, as it becomes necessary, in order to keep the number of Directors elected by the Institute equal to not less than two-thirds of the total number of both Institute and Associate Directors.

SECTION 24. Should a vacancy occur in the Board of Directors or in any elective office, except the Presidency or First Vice-Presidency, through death, resignation or other cause, the Directors may elect an Active Member to fill the vacancy until the next annual election.

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SECTION 25. The Directors shall regulate their own proceedings, and may, by resolution, delegate specific powers to an Executive Committee, or to any one or more of their members. No act of the Executive Committee, or of a delegate shall be binding until it has been approved by a resolution of the Directors.

SECTION 26. The Board of Directors shall present at the annual meeting of the Institute a report verified by the President, Secretary and Treasurer, or by a majority of the members, which shall show the state of the finances of the Institute at the date of the report; the receipts and expenditures for the fiscal year immediately preceding; the names and places of residence of the persons who have been admitted to membership in the Institute during that year, and give an account of the action taken by the Directors upon matters coming before it and recommendations as to the action to be taken by the Institute. This report shall be filed with the records of the Institute and an abstract of it shall be entered in the minutes of the proceedings of the annual meeting.

OFFICERS.

SECTION 27. At each annual meeting there shall be elected from among the Active Members a President, two Vice-Presidents, a Secretary, a Treasurer, and until otherwise provided for, five members of the Board of Directors. All of the officers shall be elected for one year, but the members of the Board of Directors shall be elected for two years. At the first general meeting ten members of the Board of Directors shall be elected, five to hold office for one year and five to hold office for two years.

SECTION 28. All elections shall be by ballot.

SECTION 29. The term of all elected officers shall begin on the adjournment of the annual meeting of the Institute at which they were elected. Officers shall continue in their respective offices until their successors have been elected and have accepted such election.

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SECTION 30. The President and the retiring Active Members of the Board of Directors shall not be eligible for re-election the following year

SECTION 31. Previous to each annual meeting it shall be the duty of the Directors to appoint a nominating committee of five members, none of whom shall be a Director. It will be the duty of this nominating committee to present at the annual meeting a list of the Active Members and Directors whom they recommend as officers for the ensuing year.

SECTION 32. Twenty or more members entitled to vote may constitute themselves a special nominating committee with the same powers as the nominating committee appointed by the Directors.

SECTION 33. The Directors shall appoint from their own number immediately after the meeting at which they are elected a finance committee of three members.

SECTION 34. The President shall take the chair at all meetings of the Institute, of the Board of Directors and of committees at which he is present. He shall determine to which general committee any matter shall be referred.

SECTION 35. In the absence of the President one of the Vice-Presidents shall take the chair, and in the absence of the President and Vice-Presidents a Chairman shall be appointed by the Directors from among their own members.

SECTION 36. The duties of the Secretary shall be to take minutes of all proceedings of the Institute and of the Board of Directors and to enter them in proper books for that purpose. He shall conduct the correspondence of the Institute, read minutes and notices of all the meetings, and also such papers and communications as are considered in the absence of their authors, and perform whatever other duties may be required in the Constitution and By-Laws appertaining to this department.

SECTION 37. The duties of the Treasurer shall be to receive and keep all annual dues and funds of the Institute, to

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keep correct accounts of same, and pay all bills approved by the President and a member of the Finance Committee, and he shall make an annual report to be submitted to the Institute.

SECTION 38. The duties of the Finance Committee shall be to audit the books, accounts and statements of the Treasurer; to invest the funds of the Institute, and to care generally for the finances of the Institute, subject to the control of the Directors.

SECTION 39. The duties of the Directors shall be to have the general management of the affairs of the Institute, and to prepare for its meetings. No paper or report that has not had the approval of the Directors shall be read at any meeting.

The Directors shall have the power to appoint, from time to time, a Committee on Arrangements from among the members to assist the Board of Directors in arranging for the meetings of the Institute. The Directors shall have power to fill for the unexpired term, any vacancies occurring by death, or resignation, in their own number, or in the general committees.

Any resolution, report or recommendation, that has not been considered and approved by the Directors, and that in the opinion of the Chair would have the effect of changing the policy of the Institute, or committing it to any new policy or opinion to which it had not theretofore been committed, should be referred, before adoption, to the Board of Directors, whose duty it shall be to report to the next regular meeting of the Institute upon such committal, if any, and its proper phrasing.

SECTION 40. There shall be two general committees, each reporting to the Board of Directors and responsible to the Board for such part of the work of the Institute as is delegated to it in accordance with the provisions of Sections 34, 41 and 42. Each committee shall be composed of six members, to be appointed each year by the President, and to serve one year.

SECTION 41. One general committee shall be called the

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Public Relations Committee, and to it shall be referred all investigations, reports, recommendations, resolutions and matters of any kind affecting the relations between the Institute, or its members, and the public, or any governing bodies, except as herein provided.

SECTION 42. One general committee shall be called the Technical Committee, and to it shall be referred all investigations, reports, recommendations, resolutions and matters of any kind having to do with the construction, operation and extension of gas works, and the conduct of the affairs of gas companies, not specifically delegated to the Public Relations Committee by Section 41, and except as herein otherwise provided.

SECTION 43. Each general committee shall have the power to appoint sub-committees. Each sub-committee shall consist of one member of the general committee, the other members being taken from the general membership of the Institute, and shall exist at the pleasure of the general committee by which it was appointed, and to which its report shall be made.

MEETINGS AND PROCEEDINGS.

SECTION 44. The annual meeting of the Institute shall be held on the third Wednesday of October of each year, at such place as shall be designated by the Institute at the previous meeting. In case of emergency the Directors shall have the power to change the time or place of meeting, or both, as so designated, by a three-fourths vote of all its members, at the call of the President, and such vote may be taken by mail.

SECTION 45. The Secretary shall send notices to all members of the Institute at least fourteen days before each general meeting, mentioning the papers to be read and any special business to be brought before the meeting.

SECTION 46. Special meetings of the Institute may be called at the option of the Directors, and the Secretary shall call a special meeting on the written request of one hundred members.

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The notices for special meetings shall be sent to all members at least three weeks before the date for which the meeting is called and shall state the business to be transacted, and no other shall be entertained.

SECTION 47. Thirteen members shall constitute a quorum.

SECTION 48. All questions, except as otherwise provided in Sections 9, 20, 28, 49 and 57, shall be decided by any convenient system of open voting, the presiding officer to have a second or casting vote when necessary.

SECTION 49. Questions of a personal nature shall be decided by ballot, and all parliamentary procedure not specifically covered by this Constitution shall be governed in accordance with Roberts' Rules of Order.

SECTION 50. Any member, with the concurrence of the presiding officer, may admit a friend to each meeting of the Institute, but such person shall not take part in any of the discussions unless permission to do so be given by the meeting.

SECTION 51. All papers read at the meetings of the Institute must relate to matters, either directly or indirectly connected with the objects of the Institute, and must be approved by the Directors before being read.

SECTION 52. All papers, drawings or models submitted to the meetings of the Institute shall be and remain the property of the authors.

SECTION 53. The President, the Junior Past-President, the First Vice-President, the Junior Past-Chairmen of the two general committees, and the Secretary shall constitute a Publication Committee, and nothing shall be included in the published reports of the Institute's PROCEEDINGS, or in any other publication issued by its authority, that has not been approved by at least two-thirds of the full membership of the Publication Committee.

SECTION 54. The Directors shall meet the day before each general meeting of the Institute, and also on such day between June 1st and September 15th, both inclusive, as may be desig-

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nated by the President by notice given at least one week in advance of meeting. Special meetings may be called when the President shall deem it necessary, and the President shall be required to call a special meeting at any time on the written request of five members of the Board. Of such meetings reasonable notice shall be given by special call, in print or writing, specifying the business to be attended to.

GEOGRAPHIC AND DISTRICT SECTIONS.

SECTION 55. A. In so far as the district associations now affiliated with the Institute carry out their agreements not to elect to voting membership any person connected in any way with the gas industry who is not directly identified with gas or electric interests within the state or district designated by the name of the association; and to consult with the Institute before undertaking any original work of interest to the gas profession, such associations will continue in affiliation with the Institute, but no further arrangements will be made for affiliation with any other association. Each and every district, or state gas, or gas and electric association, with which such agreements have been entered into, shall be entitled to elect one of its members a member of the Board of Directors of the Institute. The members so elected will be in addition to those named in Section 23, provided that the number of such associated directors shall never exceed one-third of the total membership of the Board. Should the Board of Directors provide for an executive committee, this committee shall include in its membership one man from each of the affiliated associations as long as the number of such associations does not exceed six. Thereafter there shall be on the executive committee at least six men who are members of affiliated associations and have among them membership in at least six such associations.

B. The Board of Directors may in its discretion authorize the formation of geographic sections. The territory to be included in each section shall consist of a state, or group of states.

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C. Subject to the approval of the Board of Directors of the Institute and the governing body of the geographic section in which it is located, city or district sections may be formed.

D. The geographic and city or district sections may adopt such Constitutions and By-Laws and elect such officers as they see fit, provided that nothing shall be done in violation of the Constitution and By-Laws of the American Gas Institute.

E. After giving due notice, any section may send a representative to appear before the Board of Directors of the Institute for the purpose of conferring with the Board in regard to any matters relating to the affairs of the Institute in the territory embraced by the section.

F. The secretary of the section shall report its proceedings to the Secretary of the Institute.

G. No person shall be eligible for membership in any section who is not a member of the American Gas Institute.

H. Sections may be dissolved for failure to comply with the Constitution and By-Laws of the Institute.

PROCEEDINGS.

SECTION 56. Each member of the Institute in good standing shall be entitled to and shall be furnished by the Secretary with a copy of the PROCEEDINGS of the Institute for the current year, in which shall be listed the names and addresses of the members. In any such list each member should be listed by the title, or titles, only, from which he derives his eligibility to his class of membership.

AMENDMENTS.

SECTION 57. All propositions for adding to or altering any of the provisions of the foregoing Constitution shall be laid before the Directors, who, if they see fit, may bring it before the next general meeting of the Institute, and who shall be bound to do so on the requisition in writing of any ten members of the Institute. All such propositions shall be decided by ballot and shall require two-thirds of the vote cast for their adoption.

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BY-LAWS

(Section numbers refer to corresponding Sections of the Constitution)

1. (SECTION 10.) Each member proposing a candidate for admission is required to make a confidential communication to the Secretary for forwarding to the Membership Committee, setting forth in detail such information, personally known to referee, as shall enable the Directors to decide upon the eligibility of the candidate for admission to the Institute, except that in the event of the requisite number of members in good standing having personally signed the application of a candidate, this may be deemed sufficient endorsement and the requirement of the confidential communication referred to above shall not be obligatory, but shall be optional at the discretion of the Membership Committee. The Secretary shall be the judge of the competency and the signature of referees.

2. (SECTION 10.) In the absence of replies from the referees to inquiries for information, or if replies are not sufficiently explicit, the Secretary shall cause the applicant to be notified, and the applicant shall be held in abeyance.

3. (SECTION 10.) At a meeting subsequent to their election, the Directors shall appoint from their number, four, to be a committee on election of new members. This committee shall pass on all applications for membership, and report to the Directors. Any correspondence in regard to an applicant shall be destroyed when his name has been placed upon a voting ballot, or upon withdrawal of the application.

4. (SECTION 12.) The Secretary shall, twice a year, on or about the first day of March and September, mail to each member entitled to vote, a ballot stating the names and respective grades of the candidates for membership in the Institute which have been approved by the Directors, and the time of the close of voting. The voter shall prepare his ballot by crossing out the names of candidates rejected by him, and shall enclose said ballot in a sealed blank ballot envelope, which he shall then enclose in a second sealed outer envelope

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on which he shall, for indentification, write his name in ink. The ballot thus prepared and enclosed shall be mailed or delivered unopened to the Secretary, which shall be counted as an affirmative vote on all the names not crossed out. The Secretary shall be the judge of the competency and the signature of all voters. On the close of the voting, the Secretary shall first open and destroy the outer envelopes, and shall then canvass the ballots, and certify the result to the Membership Committee.

The Secretary shall not receive any ballot after the stated time of the close of voting. A ballot without the endorsement of the voter, written in ink on the outer envelope, shall be considered as defective, and rejected by the Secretary.

The names of those persons elected to membership, with their respective grades, shall be embodied in a written report, signed by the Secretary, and presented to the next meeting of the Institute. The President shall then declare them duly elected to membership in the Institute. The Secretary may, in advance of any meeting, advise each candidate of the result of the canvass of the votes in his case. The names of applicants who are not elected shall neither be announced nor recorded in the Proceedings.

The endorser of an applicant who has not been elected, may, with his consent, present to the Directors a written request for a re-submission of his name to ballot. The Directors may, in their discretion, by a three-fourths vote of the members present, order the name of the applicant placed on the next ballot for members.

5. (SECTION 13.) Section 13 of the Constitution shall be printed upon the notification of election to all members except Honorary Members.

6. (SECTIONS 14 and 16.) The initiation fee and annual dues of the first year shall be due and payable on notice of election to membership. Bills for the fee and dues should accompany the notification of election. Thereafter the annual dues shall be due and payable on the first day of October of each year.

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7. (SECTIONS 14 and 16.) Upon payment of the initiation fee and annual dues, a newly elected member shall receive a copy of the volume of the Proceedings containing the report of the meeting held in the then current fiscal year, and copies of any other publications of the Institute, which may have been distributed without charge to the members during that year, even though the date of issue of these publications is prior to that of the election of such member.

8. Each member shall be entitled to a badge upon payment of an amount to be fixed from time to time by the Directors. Upon his ceasing to be a member, he shall return his badge, and receive therefor the sum of $2.00.

9. Each member shall be entitled to a certificate of membership in accordance with his grade, signed by the President and Secretary. Every such certificate *shall remain the property of the Institute* and shall be returned to the Secretary on demand of the Directors.

10. (SECTION 19.) The Treasurer shall present to the Directors the name of any member in arrears for more than one year.

11. (SECTION 26.) The Secretary shall furnish the Directors with the information needed for their annual report, excepting only as to finances, or to matters which have been entrusted to special committees. The financial report shall be made by the Treasurer to the Finance Committee.

12. (SECTION 26.) The fiscal year of the Institute shall begin September 1st.

13. (SECTION 28.) The President shall, at the first session of the Annual Meeting, appoint three Tellers of Election, who shall canvass the vote cast for officers, and report the result to the meeting.

14. (SECTION 31.) The Nominating Committee shall report at the first session, and a ballot be taken on their report at once unless twenty or more members object. In such case, the ballot for officers shall take place at the first session of the second day, in the manner prescribed in By-Law No. 15.

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15. (SECTION 31.) If the report of the Nominating Committee is not unanimously adopted, the Tellers of Election shall distribute ballots among the members, at once, unless the election is postponed as covered by By-Law No. 14. In either case poll may be opened outside the meeting room in some adjacent and convenient place. If there is no objection, one ballot may be cast for those nominated by the committee.

16. (SECTION 33.) When the appointment of a chairman is not included in the appointment of a committee, the latter shall elect their own chairman.

17. (SECTION 36.) The Secretary shall be in charge of the membership lists. He shall also be in charge of all other property of the Institute not distinctly pertaining to the Treasurer's work.

18. (SECTION 37.) The annual report of the Treasurer shall be embodied in the financial report of the Directors.

19. (SECTION 37.) Neither the Treasurer nor any other officer of the Institute shall pay out money except upon bills approved by the President and a member of the Finance Committee.

20. (SECTION 37.) The Treasurer shall furnish a bond for the faithful performance of his duties to such amount as the Finance Committee may require, such bond to be procured from an incorporated guarantee company at the expense of the Institute.

21. (SECTION 39.) The President, subject to subsequent approval by the Directors, may, in his discretion, appoint a member or members of the Institute to represent it at meetings of associations of kindred aim or at public functions. Such delegates should be designated as "Honorary Vice-Presidents," and their duties shall terminate with the occasion for which they are appointed.

22. (SECTION 39.) Not later than six months prior to each annual meeting of the Institute, the Directors shall appoint an Arrangement Committee to have charge of all the details connected with the annual meeting, except only as to papers.

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23. At the opening of the first session, following the election of officers, the President shall appoint a committee of three to recommend the place to be designated by the Institute for the next annual meeting.

24. (SECTION 57.) Amendments of, or additions to, the By-Laws may be adopted by the Directors by a unanimous vote at any meeting. When objection is made, two weeks' notice and copy of the proposed changes shall be sent to each Director. At any meeting subsequent to such notice, a two-thirds vote will be sufficient for adoption.

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Past Officers of the Merged Associations

AMERICAN GAS LIGHT ASSOCIATION
1873-1906

Past Presidents

*Charles Roome	1873-79	Arthur E. Boardman	1893
*William H. Price	1880-81	William H. Pearson	1894
*Andrew Hickenlooper	1882	Walton Clark	1895
*Theobald Forstall	1883	C. J. R. Humphreys	1896
*William A. Stedman	1884	Chas. H. Nettleton	1897
*Eugene Vanderpool	1885	*J. B. Crockett	1898
*Austin C. Wood	1886	Alex. C. Humphreys	1899
Malcolm S. Greenough	1887	Geo. G. Ramsdell	1900
*Thomas Turner	1888	Edward G. Pratt	1901
*Alpheus B. Slater	1889	*Wm. R. Beal	1902
Emerson McMillin	1890	Alten S. Miller	1903
John B. Harbison	1891	Rollin Norris	1904
*William Henry White	1892	E. G. Cowdrey	1905

[1]*Charles F. Prichard.

Past Secretaries

*Henry Wurtz	1873	C. J. R. Humphreys	1884-91
*Peter E. Demill	1874	A. B. Slater, Jr	1892-96
*Charles H. Nettleton	1875-79	Alfred E. Forstall	1897-04
*William Henry White	1880-83	Geo. G. Ramsdell	1905-06

OHIO GAS LIGHT ASSOCIATION
1884-1906

Past Presidents

Gen. A. Hickenlooper	1884-86	Jerome Penn	1897
Emerson McMillin	1887	W. C. Boyle	1898
Eugene Printz	1888	*B. P. Holmes, elected for	1899
*Thomas Wood	1889	*E. H. Jenkins	1899
Edw. Lindsley	1890	A. P. Lathrop	1900
*Chas. R. Faben, Jr	1891	George Whysall	1901
*H. Wilkiemeyer	1892	Henry L. Doherty	1902
Chas. H. Welch	1893	C. W. Andrews	1903
Irvin Butterworth	1894	John D. McIlhenny	1904
J. W. R. Cline	1895	F. W. Stone	1905
*Jos. Gwynn	1896	Donald McDonald	1906

[1]B. W. Perkins 1907

[1] Elected but did not serve owing to merger. * Deceased.

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OHIO GAS LIGHT ASSOCIATION–(*Continued*)

Past Secretaries

*JOSEPH M. BATE 1884-85
IRVIN BUTTERWORTH....1886-93
A. P. LATHROP 1894-98
THOMAS CLIVE JONES..1899-1906

WESTERN GAS ASSOCIATION
1878–1906

Past Presidents

*J. O. KING.....1878-80
*THOMAS BUTTERWORTH..1881-82
*J. B. HOWARD.....1883-84
T. G. LANSDEN.....1885
*JAMES SOMERVILLE.....1886
*JOHN FULLAGAR.....1887
EMERSON MCMILLIN 1888
GEORGE G. RAMSDELL ..1889
*E. G. KING, Elected for .1890
*CHARLES R. FABEN, JR..1890
FREDERIC EGNER 1891
E. G. COWDREY.....1892
*B. E. CHOLLAR.....1893
*E. H. JENKINS.....1894
ISAAC C. BAXTER.....1895
A. W. LITTLETON 1896
*W. H. ODIORNE.....1897
JAMES T. LYNN 1898
*G. TREADWAY THOMPSON 1899
WILLIAM MCDONALD....1900
I. C. COPLEY.....1901
THOMAS D. MILLER.....1902
A. H. BARRET.....1903
F. H. SHELTON 1904
O. O. THWING 1905
PAUL DOTY.....1906

[1]*KERR MURRAY MITCHELL.

Past Secretaries

*LEE A. HALL 1878-82
A. W. LITTLETON 1882-94
JAMES W. DUNBAR 1895-1906

AMERICAN GAS INSTITUTE

Past Presidents

B. W. PERKINS.....1906
WALTON CLARK.....1906-1907
ALEX. C. HUMPHREYS·1907-1908
*CHAS. F. PRICHARD...1908-1909
W. H. BRADLEY.....1909-1910
DONALD MCDONALD...1910-1911
IRA C. COPLEY.....1911-1912
W. R. ADDICKS 1912-1913

Past Secretaries

JAMES W. DUNBAR....1906-1908
A. B. BRADLE.....1908-1911
GEO. G. RAMSDELL....1911-

[1] Elected but did not serve owing to merger. * Deceased.

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MEMBERS

OF THE

AMERICAN GAS INSTITUTE

HONORARY MEMBERS.

BONE, PROF. WILLIAM A., September, 1912.
Professor in the Imperial College of Science and Technology, South Kensington, London, S. W., England.

CHANDLER, CHARLES F., PH. D., M. D., LL. D., D. Sc., September, 1910.
51 East 54th Street, New York, N. Y.

KING, WILLIAM, September, 1910.
5 Beach Lawn, Waterloo, Liverpool, England.

WOODALL, SIR CORBET, September, 1910.
Palace Chambers, Bridge Street, Westminster, S. W., London, England.

LIFE MEMBER.

SLATER, ALPHEUS B., October, 1906.
Consulting Engineer, Slocums, Rhode Island.

ACTIVE MEMBERS.

ABELL, H. C., October, 1906.
Engineer, American Light & Traction Company, 40 Wall Street, New York, New York.

ADAMS, B. C., October, 1906.
General Manager, Spokane Gas & Fuel Company, Spokane, Washington.

ADAMS, H. C., October, 1906.
Vice-President, Westmoreland Coal Company, 224 South Third Street, Philadelphia, Pennsylvania.

ADAMS, ROBERT MORFORD, March, 1913.
Secretary and Treasurer, Los Angeles Gas & Electric Corporation, 645 South Hill Street, Los Angeles, California.

ADDICKS, WALTER R., October, 1906.
Vice-President, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

AFRICA, WALTER G., October, 1906.
Treasurer and Manager, Peoples Gas Light Company, 39 Hanover Street, Manchester, New Hampshire.

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ALDEN, JOHN DOUGLAS, March, 1910.
Assistant Superintendent, United Gas Improvement Company, Waterbury, Connecticut.

ALDRICH, W. A., October, 1906.
Engineer, 23 North Lafayette Street, Grand Rapids, Michigan.

ALLEN, WILLIAM H., JR., September, 1909.
Superintendent, By-Products Coke Corporation, Semet-Solvay Coke Ovens, South Chicago, Illinois.

ALLISON, WALTER A., October, 1906.
Engineer, C. H. Geist Company, 1127 Land Title Building, Philadelphia, Pennsylvania.

ALLYN, GEORGE E., October, 1906.
Superintendent of Distribution, Providence Gas Company, 20 Market Square, Providence, Rhode Island.

ALMBERG, H. E., September, 1913.
Attorney for Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

ALRICH, HERBERT W., March, 1909.
Assistant Engineer of Construction, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

ALTHEN, GEORGE R., September, 1912.
Superintendent of Distribution, Gas Division, Consolidated Gas, Electric Light & Power Company, Lexington and Liberty Streets, Baltimore, Maryland.

ALTHOUSE, A. J., September, 1912.
Superintendent, Hamburg Gas & Electric Company, Hamburg, Pennsylvania.

AMES, KNOWLTON L., October, 1906.
Jacksonville Gas Company, 108 South La Salle Street, Chicago, Illinois.

ANDERSON, EDGAR VOORHEES, September, 1910.
Gas Engineer, Central Hudson Gas & Electric Company, 50 Market Street, Poughkeepsie, New York.

ANDERSON, HOWARD BRUCE, September, 1911.
Superintendent City District, The United Gas Improvement Company, 1931 South 9th Street, Philadelphia, Pennsylvania.

ANDERSON, WILLIAM C., October, 1906.
Manager, Luzerne County Gas & Electric Company, 247 Wyoming Avenue, Kingston, Pennsylvania.

ANDREWS, CHARLES HAROLD, March, 1912.
Assistant General Manager, North Carolina Public Service Company, Greensboro, North Carolina.

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ANDREWS, C. W., October, 1906.
Treasurer, Zenith Furnace Company, 404 West First Street, Duluth, Minnesota.

ANDREWS, J. CHARLES, October, 1906.
Turner Construction Company, 11 Broadway, New York, New York.

ANGELL, FREDERIC J., September, 1908.
Mechanical Engineer, 38 Victoria Street, Westminster, London, S. W., England.

ARKWRIGHT, P. S., October, 1906.
Vice-President, Atlanta Gas Light Company, Electric & Gas Building, Atlanta, Georgia.

ARMSTRONG, H. V., March, 1912.
Engineer, Northern Indiana Gas & Electric Company, Michigan City, Indiana.

ARMSTRONG, J. H. N., March, 1911.
Statistician, Consolidated Gas Company, 124 East 15th Street, New York, New York.

ARTHUR, F. M., October, 1906.
District Superintendent, United Gas Improvement Company, 1615 North 9th Street, Philadelphia, Pennsylvania.

ASHWORTH, JAMES, September, 1910.
Superintendent of Distribution, Public Service Gas Company, St. Paul and St. James Avenues, Jersey City, New Jersey.

ATWOOD, C. CASSELS, October, 1906.
Superintendent, New Amsterdam Gas Company, Vernon and Webster Avenues, Long Island City, New York.

AYRES, CHESTER T., September, 1908.
Works Manager, Union Carbide & Electro-Metallurgical Company, 30 East 42d Street, New York, New York.

BAEHR, WILLIAM ALFRED, October, 1906.
Consulting Engineer, Peoples Gas Building, Chicago, Illinois.

BAINS, GEORGE B., 3D, October, 1906.
Engineer, Consumers Gas Company, 441 Penn Street, Reading, Pennsylvania.

BALL, JAMES, October, 1906.
Assistant Secretary and Treasurer, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

BALL, SAMUEL, September, 1911.
Manager, Bay City Gas Company, 520 Centre Avenue, Bay City, Michigan.

BARKER, PERRY, September, 1911.
Fuel Engineer, Arthur D. Little, Inc., 93 Broad Street, Boston, Massachusetts.

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BARKER, WILLIAM S., September, 1911.
Assistant to Comptroller, Public Service Gas Company, 763 Broad Street, Newark, New Jersey.

BARLOW, THADDEUS SCOTT, September, 1910.
Superintendent, Consolidated Gas Company, 302 East 99th Street, New York, New York.

BARNES, ALBERT MALLARD, September, 1907.
President and General Manager, Cambridge Gas Light Company, 719 Massachusetts Avenue, Cambridge, Massachusetts.

BARNITZ, F. R., September, 1908.
General Superintendent, Commercial Department, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

BARNUM, DANA DWIGHT, March, 1911.
General Manager, Worcester Gas Light Company, 240 Main Street, Worcester, Massachusetts.

BARRET, A. H., October, 1906.
Retired, Louisville Gas Company, 5 Board of Trade Building, Louisville, Kentucky.

BARRETT, WILLIAM E., October, 1906.
Gas Engineer, J. G. White Management Corporation, 43 Exchange Place, New York, New York.

BARRETT, WILLIAM FELTON, September, 1908.
Consulting Engineer, 42d Street Building, 30 East 42d Street, New York, New York.

BARROWS, GEORGE S., October, 1906.
Gas and Electric Utilization Division, The United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

BARTHOLD, W. H., October, 1906.
Gas Engineer, Hodenpyl, Hardy & Company, 14 Wall Street, New York, New York.

BATTEN, J. W., March, 1909.
Engineer, Detroit City Gas Company, Gas Office Building, Detroit, Michigan.

BATTIN, HENRY S., October, 1906.
Assistant to General Superintendent, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

BATTIN, ISAAC, October, 1906.
Retired, Engineer, Omaha Gas Company, 8047 Walker Street, Holmesburg, Philadelphia, Pennsylvania.

BATTIN, WM. INGRAM, March, 1910.
Engineer, Indiana Lighting Company, 911 Pontiac Street, Lafayette, Indiana.

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BAURHYTE, WILLIAM, October, 1906.
Vice-President, Los Angeles Gas & Electric Corporation, 645 South Hill Street, Los Angeles, California.

BAXTER, ISAAC C., October, 1906.
Upland, San Bernardino County, California.

BAYLY, C. CLAY, October, 1906.
Assistant to Engineer, Washington Gas Light Company, Twenty-sixth and G Streets, Washington, District of Columbia.

BEADENKOPF, GEORGE, October, 1906.
Engineer, Consolidated Gas, Electric Light & Power Company, Lexington and Liberty Streets, Baltimore, Maryland.

BEADLE, ALBERT B., October, 1906.
Consulting Gas Engineer, 1328 Chestnut Street, Philadelphia, Pennsylvania.

BEAL, A. R., October, 1906.
District Superintendent, Central Hudson Gas & Electric Company, Newburgh, New York.

BEAL, T. R., October, 1906.
President, Central Hudson Gas & Electric Company, 309 Main Street, Poughkeepsie, New York.

BEAUMONT, WALTER W., September, 1907.
Assistant Superintendent, Street Lighting Department, The Equitable Illuminating Company, 24 North 22d Street, Philadelphia, Pennsylvania.

BECHER, EUGEN, March, 1913.
Chief Engineer, Blaugas Company of America, 25 Madison Avenue, New York, New York.

BECK, GEORGE W., October, 1906.
Superintendent, Sunbury Gas Company, Sunbury, Pennsylvania.

BELL, CLEMENT H., September, 1910.
Manager and Superintendent, Watertown Light & Power Company, Watertown, South Dakota.

BELL, ERNEST WILLIAM, October, 1906.
Consulting Engineer, Room 1425, 165 Broadway, New York, New York.

BENEDICT, CLARENCE M., September, 1908.
Assistant Secretary and Treasurer, Charleston Consolidated Railway & Lighting Company, Charleston, South Carolina.

BENNETT, CHARLES W., October, 1906.
General Manager, Binghamton Gas Works, 40 Chenango Street, Binghamton, New York.

BENSON, FREDERICK SHEPARD, JR., March, 1911.
Superintendent, Nassau Works, Brooklyn Union Gas Company, 556 Kent Avenue, Brooklyn, New York.

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BERKLEY, Jos. M., October, 1906.
Superintendent and Engineer, Southern California Gas Company, 624 Pacific Electric Building, Los Angeles, California.

BERTKE, W. A., September, 1909.
Superintendent, Gas Plants, Pacific Power & Light Company, North Yakima, Washington.

BERTKE, WILLIAM JOHN, October, 1907.
Engineer, Sioux City Gas & Electric Company, 3519 Jackson Street, Sioux City, Iowa.

BERTRAND, PHILIP A., October, 1906.
General Manager, Grays Harbor Railway & Light Company, Aberdeen, Washington.

BEUGLER, HUGH M., September, 1913.
Operating Manager, Central Hudson Gas & Electric Company, 50 Market Street, Poughkeepsie, New York.

BILL, BENJAMIN P., October, 1906.
Superintendent, Springfield Gas Light Company, 23 State Street, Springfield, Massachusetts.

BIMSON, JOHN, JR., September, 1909.
Superintendent Distribution, Public Service Gas Company, Paterson, New Jersey.

BIRD, VIGGO EDWARD, September, 1910.
Manager, New London Gas & Electric Division, Connecticut Power Company, 33 Union Street, New London, Connecticut.

BISHOP, ROOKWOOD COMFORT, March, 1911.
General Manager, Christchurch Gas, Coal & Coke Company, Ltd., 77 Worcester Street, Christchurch, New Zealand.

BISSELL, WEST, October, 1906.
Civil Engineer, Care of Mrs. Kennedy, 27 Park Street, Jersey City, New Jersey.

BIXBY, HOWARD, October, 1906.
General Manager, Gas Company, Red Wing, Minnesota.

BLACKIE, JOHN F., March, 1911.
Assistant Superintendent, Milwaukee Coke & Gas Company, Milwaukee, Wisconsin.

BLACKWELL, HUBERT C., September, 1912.
General Superintendent, Peoples Light Company, 208 West High Street, Davenport, Iowa.

BLAKE, FRANCIS J., September, 1912.
Superintendent Manufacturing, Nashville Gas & Heating Company, 722 Second Avenue North, Nashville, Tennessee.

BLAUVELT, WILLIAM HUTTON, March, 1911.
Consulting Engineer, Semet-Solvay Company, Syracuse, New York.

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BLAUVELT, WARREN S., October, 1906.
Superintendent, Detroit Plant, Delray Station, Semet-Solvay Company, Post Office Box 11, Detroit, Michigan.

BLOWERS, FRANK W., October, 1906.
Secretary and General Manager, Kalamazoo Gas Company, Kalamazoo, Michigan.

BOARDMAN, A. E., October, 1906.
Villa Canto Sereno, Locarno, Minusio, Switzerland.

BODINE, SAMUEL TAYLOR, October, 1906.
President, The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

BOGERT, W. RUSSELL, March, 1911.
Assistant Superintendent, Consolidated Gas Company, 130 East 15th Street, New York, New York.

BOND, CHARLES O., March, 1907.
Manager, United Gas Improvement Company Photometrical Laboratory, 3101 Passyunk Avenue, Philadelphia, Pennsylvania.

BOONE, CHARLES, October, 1906.
Engineer, Metropolitan Works, Brooklyn Union Gas Company, 579 5th Street, Brooklyn, New York.

BOOTH, ARTHUR, September, 1909.
Assistant General Purchasing Agent, Philadelphia Company, 435 Sixth Avenue, Pittsburgh, Pennsylvania.

BOOTH, W. F., March, 1909.
Manager, Little Rock Gas & Fuel Company, Little Rock, Arkansas.

BORGNER, CYRUS, October, 1906.
President, Cyrus Borgner Company, 234 North Twenty-third Street, Philadelphia, Pennsylvania.

BOYD, ALBERT MATTHEW, October, 1906.
Assistant to General Superintendent, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

BRADLEY, CHARLES W., October, 1906.
Engineer, Northwestern Gas Light & Coke Company, 115 North Oak Park Avenue, Oak Park, Illinois.

BRADLEY, WILLIAM H., October, 1906.
Chief Engineer, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

BRADY, JAMES C., March, 1907.
Director, New Amsterdam Gas Company, 54 Wall Street, New York, New York.

BRADY, JOHN T., October, 1906.
Treasurer, Denver Gas & Electric Company, 900 Fifteenth Street, Denver, Colorado.

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BRAINE, JOHN H., October, 1906.
Superintendent, Holder Distribution Department, Brooklyn Union Gas Company, 84 Broadway, Brooklyn, New York.

BREDEL, FRED, October, 1906.
Gas Engineer, 405 Keene Street, Milwaukee, Wisconsin.

BREWER, JOSEPH H., September, 1912.
Vice-President, Kelsey & Brewer Company, Grand Rapids, Michigan.

BRITSCH, MATHIAS, October, 1906.
Superintendent, Cicero Station, Northwestern Gas Light & Coke Company, Lombard Avenue and G. W. Tracks, Oak Park, Illinois.

BRITTON, JOHN A., October, 1906.
Vice-President and General Manager, Pacific Gas & Electric Company, 445 Sutter Street, San Francisco, California.

BRODNAX, WM. F., October, 1907.
14 Eighth Avenue, Bethlehem, Pennsylvania.

BROWN, CHARLES H., September, 1912.
Superintendent, Bluefield Gas & Power Company, Bluefield, West Virginia.

BROWN, ERNEST C., October, 1906.
Secretary and Treasurer, Boone (Iowa) Gas Company, Editor *The Gas Age*, 280 Broadway, New York, New York.

BROWN, JAMES A., September, 1911.
Gas Engineer, with Hodenpyl, Hardy & Company, 2004 Dime Bank Building, Detroit, Michigan.

BROWN, R. B., October, 1906.
General Manager and Chief Engineer, Milwaukee Gas Light Company, 182 Wisconsin Street, Milwaukee, Wisconsin.

BROWN, ROBERT E., October, 1906.
General Manager, Consumers Power Company, 132 South Front Street, Mankato, Minnesota.

BROWN, SAMUEL W., September, 1910.
Superintendent, Gas Department, Columbia Railway, Gas & Electric Company, 2805 Wilson Street, Columbia, South Carolina.

BRUCE, HOWARD, October, 1906.
Vice-President, Bartlett Hayward & Company, Continental Building, Baltimore, Maryland.

BRUFF, CHARLES L., March, 1911.
Combustion Engineer, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

BRUNDAGE, HENRY M., September, 1908.
Assistant Secretary, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

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BRUNDRETT, ERNEST L., October, 1906.
President, Kansas City Gas Company, 910 Grand Avenue, Kansas City, Missouri.

BRUSH, DANIEL HARMON, JR., March, 1912.
Assistant Superintendent, Calumet Division, Peoples Gas Light & Coke Company, 9051 Commercial Avenue, Chicago, Illinois.

BRYANS, HENRY BUSSELL, March, 1908.
Assistant to Inspecting Engineer, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

BRYANT, CHARLES F., October, 1906.
Auditor, Westchester Lighting Company, Mount Vernon, New York.

BUCK, H. M., October, 1906.
Waukesha, Wisconsin.

BUCKLEY, MARTIN F., March, 1913.
Foreman, Consolidated Gas Company, 501 East 21st Street, New York, New York.

BUCKMINSTER, ROLLIN, September, 1908.
Superintendent, Lowell Gas Light Company, 306 School Street, Lowell, Massachusetts.

BULL, DAVID M., September, 1913.
Assistant Superintendent, Consolidated Gas Company, 99th Street and 2nd Avenue, New York, New York.

BULLARD, JOHN ERVIN, March, 1913.
Manager, New Business Department, Public Service Corporation of Long Island, Port Washington, New York.

BULLOCK, B. F., October, 1906.
Superintendent, City Gas Works, Municipal Plant, Fredericksburg, Virginia.

BUMP, MILAN R., October, 1906.
Care of H. L. Doherty & Co., 60 Wall Street, New York, New York.

BUNKER, THEODORE, October, 1906.
Engineer, Gas Department, Passaic Division, Public Service Gas Company, East 5th Street Gas Works, Paterson, New Jersey.

BURCOMBE, NORMAN SMITH, March, 1911.
Manager, Grays Harbor Gas Company, 103 West Heron Street, Aberdeen, Washington.

BURDEN, WESLEY W., September, 1909.
Mechanical Engineer, Astoria Light, Heat & Power Company, Astoria, Long Island, New York.

BURGESS, C. F., October, 1906.
Northern Chemical Engineering Laboratories, Madison, Wisconsin.

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BURGI, HERMAN, October, 1906.
General Superintendent, Gas Light Company, State and Water Streets, Springfield, Massachusetts.

BURKHART, HENRY W., March, 1910.
Superintendent, Gas Department, Southern California Edison Company, Los Angeles, California.

BURLEIGH, JOHN J., September, 1907.
Second Vice-President, Public Service Gas Company, 418 Federal Street, Camden, New Jersey.

BURRITT, DWIGHT F., September, 1907.
General Superintendent, National Gas, Electric Light & Power Company, 1714 Ford Building, Detroit, Michigan.

BURT, AUSTIN, October, 1906.
Manager, Citizens Gas & Electric Company, 308 East 4th Street, Waterloo, Iowa.

BUSH, ROBERT WILDER, October, 1906.
Engineer of Manufacture, Brooklyn Union Gas Company, Kent Avenue and Cross Street, Brooklyn, New York.

BUTLER, JOHN MORRIS, September, 1913.
Secretary and Treasurer, Bronx Gas & Electric Company, Westchester, New York.

BUTTERWORTH, C. W., October, 1906.
Care Gas Company, Rockford, Illinois.

BUTTERWORTH, IRVIN, October, 1906.
Vice-President, Detroit City Gas Company, 121 Ferry Avenue, East, Detroit, Michigan.

BYRNE, EDWARD J., October, 1906.
Engineer of Citizens Works, Brooklyn Union Gas Company, Fifth and Hoyt Streets, Brooklyn, New York.

BYRNE, EDWARD LOUIS, September, 1910.
Superintendent, Fulton Works, The Brooklyn Union Gas Company, 265 Nevins Street, Brooklyn, New York.

BYRNE, THOMAS E., October, 1906.
Chief Engineer, Kings County Lighting Company, 4802 New Utrecht Avenue, Brooklyn, New York.

CABELL, JOHN L., September, 1908.
Superintendent, Savannah Gas Company, 9 Congress Street, Savannah, Georgia.

CABOT, JOHN, October, 1906.
President, Cabot Manufacturing Company, 1421 Clinton Street, Hoboken, New Jersey.

CADWALLADER, L. L., October, 1906.
Manager, Chambersburg Gas Company, Chambersburg, Pennsylvania.

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CAFFREY, GEORGE HENRY, March, 1913.
With Havana Railway, Light & Power C
Havana, Cuba.

CAHILL, WILLIAM J., October, 1906.
General Manager, Gas Department, Utica
pany, 222 Genesee Street, Utica, New Yo

CALHOUN, ERVIN, September, 1913.
Superintendent of Stores, Philadelphia G
Improvement Company, 19th Street an
Philadelphia, Pennsylvania.

CALLENBACH, J. ANTON, October, 1906.
Chemist, Camden Coke Company, 131 Ma
ville, New Jersey.

CALLENDAR, ELBERT P., October, 1906.
President, *American Gas Light Journal,*
New York, New York.

CAMPBELL, ALEX. J., October, 1906.
General Manager, United Electric Light
Waterbury, Connecticut.

CAMPBELL, S. K., October, 1906.
Editor, *American Gas Light Journal,* 42 P
New York.

CARBONELL, CORNELIUS M., September, 1913.
Assistant Secretary, Astoria Light, Heat
Astoria, Long Island, New York.

CARNES, FRANK S., September, 1908.
Superintendent South Division Street Dep
Light & Coke Company, 38 West 64th Stre

CARPENTER, HAROLD, September, 1907.
Resident Engineer, Astoria Tunnel, The A
Power Company, 977 Whitlock Avenue, N

CARROLL, LAFAYETTE D., September, 1908.
Mechanical Engineer, 38 Victoria Street, I
land.

CARSON, GEORGE S., October, 1906.
President, Iowa Gas & Electric Company, W

CARTER, ROBERT A., September, 1907.
Vice-President, Consolidated Gas Company
East 15th Street, New York, New York.

CARTER, ROBERT A., JR., September, 1908.
Superintendent, Water Gas Plant, Astoria L
Company, 124 East 15th Street, New York,

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CASTOR, WILLIAM A., October, 1906.
Superintendent of Meters, United Gas Improvement Company, 1646 Dyre Street, Frankford, Philadelphia, Pennsylvania.

CATHELS, EDMUND, October, 1906.
Engineer, 28 Plain Street, Providence, Rhode Island.

CAUSEBROOK, W. R., September, 1907.
Agent, Gas and Electric Departments, Public Service Gas Company, 210 Park Avenue, Plainfield, New Jersey.

CHADWELL, WILLIAM H., September, 1907.
Superintendent, Market Street Gas Works, Public Service Gas Company, Newark, New Jersey.

CHAMBERLAIN, GLENN R., October, 1906.
Secretary and Manager, Commercial Department, Grand Rapids Gas Light Company, Pearl and Ottawa Streets, Grand Rapids, Michigan.

CHANNON, HARRY O., March, 1911.
Manager, Quincy Gas, Electric & Heat Company, 422 Main Street, Quincy, Illinois.

CHAPIN, C. H. B., September, 1913.
Secretary, Empire State Gas & Electric Association; Secretary, Joint Committee on Calorimetry for New York State, 29 West 39th Street, New York, New York.

CHAPMAN, HARLEN MONROE, September, 1913.
Superintendent, Semet-Solvay Company, Indianapolis, Indiana.

CHENEY, HERBERT NEAL, March, 1911.
Engineer of Construction, Boston Consolidated Gas Company, 24 West Street, Boston, Massachusetts.

CHEWNING, WALTER L., September, 1907.
Construction Department, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

CHICHESTER, ALFRED A., October, 1906.
Division Superintendent, Peoples Gas Light & Coke Company, 440 East Forty-second Place, Chicago, Illinois.

CHOLLAR, BYRON E., October, 1906.
Gas Engineer, 2840 Troost Avenue, Kansas City, Missouri.

CHUBB, CHESTER N., October, 1906.
Vice-President and Manager, Northern Indiana Gas & Electric Company, 519 Franklin Street, Michigan City, Indiana.

CHUBBUCK, H. E., October, 1906.
Vice-President Executive, Illinois Traction System, Peoria, Illinois.

CLABAUGH, G. W., October, 1906.
Vice-President and Secretary, Omaha Gas Company, 1509 Howard Street, Omaha, Nebraska.

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CLARK, HORACE HERBERT, March, 1910.
Superintendent of Mains and Services, The Northwestern Gas Light & Coke Company, 115 North Oak Park Avenue, Oak Park, Illinois.

CLARK, JOHN A., JR., October, 1906.
Engineer of Distribution, Public Service Gas Company, 35 Front Street, Newark, New Jersey.

CLARK, JOHN C. D., October, 1906.
Manager, Utah Gas & Coke Company, Salt Lake City, Utah.

CLARK, ROBERT BROWNING, March, 1911.
Superintendent of Works, Fall River Gas Works Company, 512 High Street, Fall River, Massachusetts.

CLARK, WALTON, October, 1906.
Second Vice-President, The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

CLARK, WILLIAM J., October, 1906.
Vice-President, Westchester Lighting Company, 1st Avenue and 1st Street, Mount Vernon, New York.

CLARK, W. VAN ALAN, March, 1912.
Assistant Superintendent, Astoria Light, Heat & Power Company, Astoria, Long Island, New York.

CLARKE, ALFRED, March, 1908.
President, Various Gas Companies, 131 State Street, Boston, Massachusetts.

CLARY, EDWARD D., October, 1906.
Superintendent, Burlington Gas Light Company, 3d and Washington Streets, Burlington, Iowa.

CLAUSEN, WILLIAM F., October, 1906.
General Manager, Winona Gas Light & Coke Company, Winona, Minnesota.

CLINE, W. B., October, 1906.
President, Los Angeles Gas & Electric Corporation, 645 South Hill Street, Los Angeles, Caliornia.

COATE, P. S., October, 1906.
Manager and Secretary-Treasurer, Chatham Gas Company, Limited, King Street, West, Chatham, Ontario, Canada.

COBB, B. C., October, 1906.
Vice-President, Bay City (Michigan) Gas Company, Hodenpyl, Hardy & Co., 14 Wall Street, New York, New York.

COBB, S. P., October, 1906.
Superintendent, Gas Department, Albany Southern Railroad Company, Albany, New York.

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COHN, CHAS. M., September, 1907.
Vice-President, Consolidated Gas, Electric Light & Power Company, 100 West Lexington Street, Baltimore, Maryland.

COLE, C. M., October, 1906.
Superintendent, Harrisburg Gas Company, Harrisburg, Pennsylvania.

COLE, GEORGE M., October, 1906.
Vice-President and Manager, Plattsburgh Gas & Electric Company, 30 Margaret Street, Plattsburgh, New York.

COLE, WILLIAM W., October, 1906.
General Manager, Day & Zimmerman, Engineers, 608 Chestnut Street, Philadelphia, Pennsylvania.

COLLIN, H. M., September, 1912.
General Manager, Glenns Falls Gas & Electric Light Company, 11 Warren Street, Glenns Falls, New York.

COLLINS, CARROLL, October, 1906.
Manager, Marshall Gas Light Company, East State Street, Marshall, Michigan.

COLLINS, DAVID J., October, 1906.
Sales Agent, The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

COLLINS, HENRY P., October, 1906.
Manager, Herkimer County Light & Power Company, 587 Albany Street, Little Falls, New York.

COLLINS, J. CLARENCE, September, 1909.
Secretary and Auditor, Rochester Railway & Light Company, 34 Clinton Street North, Rochester, New York.

COLQUHOUN, EDWARD M., September, 1908.
Travelling New Business Agent, The United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

COLVIN, J. E., October, 1906.
Superintendent, Muncie Gas Light & Fuel Company, 301 East Main Street, Muncie, Indiana.

COMBS, ROGER B., October, 1906.
General Manager, Nashville Gas & Heating Company, Nashville, Tennessee.

COMSTOCK, C. A., March, 1911.
General Manager, Gas & Electric Company, Watertown, Wisconsin.

CONGDON, RICHARD C., October, 1906.
Secretary and General Manager, Atlanta Gas Light Company, Atlanta, Georgia.

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CONLEE, GEORGE D., September, 1913.
Superintendent, Chuctanunda Gas Light Company, 33 Market Street, Amsterdam, New York.

CONNERS, MATHIAS, October, 1906.
Superintendent, Peoples Gas Light & Coke Company, 31st Street and Pitney Court, Chicago, Illinois.

CONOVER, ERNEST R., September, 1913.
Superintendent, Westchester Lighting Company, 7 West Main Street, Tarrytown, New York.

COOK, CHAS. G., September, 1907.
Agent, Gas and Electric Departments, Public Service Gas Company, 222 East State Street, Trenton, New Jersey.

COOK, HENRY R., JR., September, 1907.
Assistant to General Superintendent, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

COOKE, ALFRED S., October, 1906.
Manager, Citizens Gas & Electric Company, Terre Haute, Indiana.

COOPER, WM. H., October, 1906.
Vice-President, Chuctanunda Gas Light Company, 96 Church Street, Amsterdam, New York.

COPLEY, HON. IRA C., October, 1906.
President, Western United Gas & Electric Company, Aurora, Illinois.

CORNINE, MARSHALL, March, 1911.
Superintendent, Repair Shops, Consolidated Gas Company, 21st Street and 1st Avenue, New York, New York.

CORNISH, R. C., October, 1906.
Engineer, American Gas Company, West Washington Square, Philadelphia, Pennsylvania.

CORSCOT, JOHN, October, 1906.
Vice-President, Madison Gas & Electric Company, 126 East Main Street, Madison, Wisconsin.

CORTELYOU, GEORGE B., March, 1912.
President, Consolidated Gas Company of New York, 4 Irving Place, New York, New York.

CORTIS, DWIGHT T., October, 1906.
Manager, Boston Gas Appliance Exchange, 175 Dartmouth Street, Boston, Massachusetts.

COVERT, IRA C., September, 1907.
Division Superintendent, Central Indiana Gas Company, Marion, Indiana.

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COWDERY, EDWARD G., October, 1906.
Vice-President, Peoples Gas Light & Coke Company, Peoples Gas Building, Chicago, Illinois.

COWPERTHWAIT, B. W., October, 1906.
Manager, Consumers Power Company, Central Avenue, Faribault, Minnesota.

COWPERTHWAIT, GEORGE E., September, 1912.
Secretary and Superintendent, Danbury & Bethel Gas & Electric Light Company, 238 Main Street, Danbury, Connecticut.

CRAFTS, HARRY C., October, 1906.
Manager, Pittsfield Coal Gas Company, 30 South Street, Pittsfield, Massachusetts.

CRAHAN, B. J., October, 1906.
Superintendent, Joplin Gas Company, 318 Joplin Street, Joplin, Missouri.

CRANE, WILLIAM M., October, 1906.
President, New Bern Gas Company, New Bern, North Carolina; 20 West 32d Street, New York, New York.

CRAWFORD, H. T., October, 1906.
Cashier, Waukegan Gas Company, Waukegan, Illinois.

CRAWFORD, THOMAS, March, 1907.
General Manager, Clinton Gas Light & Coke Company, Clinton, Iowa.

CREIGHTON, JOHN THOMAS, March, 1913.
Superintendent Gas Manufacture, Los Angeles Gas & Electric Corporation, 645 South Hill Street, Los Angeles, California.

CRESSEY, FRANK A., JR., September, 1912.
Manager, Modesto Gas Light, Coal & Coke Company, Modesto, California.

CRESSLER, A. D., October, 1906.
President, The Kerr Murray Company, Peoples Gas Building, Chicago, Illinois.

CRESSON, B. F., October, 1906.
President, Easton Gas & Electric Company, 2d and Ferry Streets, Easton, Pennsylvania.

CRIGHTON, D. K., October, 1906.
Engineer, Gas Machinery Company, 1900 Euclid Avenue, Cleveland, Ohio.

CRILLEY, ROGER, October, 1906.
General Foreman, Elizabethtown Gas Light Company, 19 Loomis Street, Elizabeth, New Jersey.

CRISFIELD, J. A. P., October, 1906.
Engineer, The United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

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CROSS, CHARLES ALFRED, March, 1911.
Engineer, Williamsburgh Works, Brooklyn Union Gas Company, foot of North 12th Street, Brooklyn, New York.

CROSS, FRANK L., March, 1909.
General Manager, Madison Gas & Electric Company, 1020 Sherman Avenue, Madison, Wisconsin.

CROSS, PHILIP, October, 1906.
Superintendent, New Business Department, Fuel Appliances, Consolidated Gas Company, 130 East 15th Street, New York, New York.

CROWELL, F. B., October, 1906.
Consulting and Contracting Engineer, 1020 Fourth National Bank Building, Atlanta, Georgia.

CROWLEY, JOHN P., October, 1906.
Secretary and Treasurer, St. Paul Gas Light Company, St. Paul, Minnesota.

CRUMP, RALPH LEE, September, 1912.
Consulting Engineer, with Ford, Bacon & Davis, 921 Canal Street, New Orleans, Louisiana.

CRUTCHER, WILLIAM H., September, 1911.
Superintendent, Gas Department, Louisville Gas & Electric Company, 311 West Chestnut Street, Louisville, Kentucky.

CURRAN, G. W., October, 1906.
Secretary, The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

CURTIS, GEORGE W., September, 1907.
Superintendent, Camden Coke Works, Gas Department, Camden, New Jersey.

CURTIS, SAMUEL P., October, 1906.
General Manager, American Gas Company, West Washington Square, Philadelphia, Pennsylvania.

CUSHMAN, CHARLES P., March, 1909.
First Vice-President, Osaka Gas Company, Limited, Osaka, Japan.

CUSHMAN, GEORGE HERBERT, September, 1908.
Superintendent, Electric Department, San Antonio Gas & Electric Company, 504 Goliad Street, San Antonio, Texas.

CUTCHEON, FREDK. RICHARD M., March, 1913.
General Manager, Consolidated Gas Company of New Jersey, 176 Broadway, Long Branch, New Jersey.

CUTCHEON, MAX H., March, 1913.
Industrial Gas Engineer, 710 Union Trust Building, Detroit, Michigan.

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DAILY, JAMES MADISON, March, 1913.
General Manager, Pueblo Gas & Fuel Company, 514 North Main Street, Pueblo, Colorado.

DALES, JAMES STEWART, October, 1906.
Secretary, Water, Light & Power Company, Franklin, Indiana.

DALLAS, ROBERT E., September, 1908.
Assistant Commercial Agent, The United Gas Improvement Company, 1035 Market Street, Philadelphia, Pennsylvania.

DALY, AUGUSTIN J., October, 1906.
Superintendent City District, Laclede Gas Light Company, 2655 Adams Street, St. Louis, Missouri.

DALY, MARTIN B., October, 1906.
President and General Manager, East Ohio Gas Company, 1447 East 6th Street, Cleveland, Ohio.

DANFORTH, BYRON HAMILTON, March, 1913.
General Manager, Indiana Fuel & Light Company, Cedar and 9th Streets, Auburn, Indiana.

DASHIELL, P. T., October, 1906.
Assistant Engineer of Works, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

DAUGHERTY, GEORGE, October, 1906.
General Manager, Trumbull Public Service Company, 409 Adams Street, Warren, Ohio.

DAVIDSON, EDWARD S., October, 1906.
District Manager, Illinois Northern Utilities Company, DeKalb, Illinois.

DAVIES, EDWARD LIVINGSTON, September, 1912.
Gas Superintendent, Queens Boro Gas & Electric Company, Far Rockaway, Long Island, New York.

DAVIES, H. W., October, 1906.
Superintendent, Pintsch Compressing Company, 303 South 30th Street, Philadelphia, Pennsylvania.

DAVIES, JAMES E., September, 1908.
Division Superintendent and Manager, Calumet Division, Peoples Gas Light & Coke Company, 9051 Commercial Avenue, Chicago, Illinois.

DAVIS, ALBERT G., March, 1911.
Chief Chemist, Consolidated Gas Company, 435 6th Avenue, Pittsburgh, Pennsylvania.

DAVIS, ERNEST H., October, 1906.
Treasurer, Northern Central Gas Company, Lewistown, Pennsylvania, West and Willow Streets, Williamsport, Pennsylvania.

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DAVIS, GEORGE H., September, 1912.
Member of firm Ford, Bacon & Davis, Engineers, 921 Canal Street, New Orleans, Louisiana.

DAVIS, R. N., March, 1907.
Assistant Superintendent, care Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

DAWES, RUFUS C., October, 1906.
President, Mobile (Alabama) Gas Company, 111 West Monroe Street, Chicago, Illinois.

DAY, ADDISON BLANCHARD, March, 1913.
Manager of Operation, Los Angeles Gas & Electric Corporation, 645 South Hill Street, Los Angeles, California.

DAY, C. L., October, 1906.
General Superintendent, Street and Meter Department, Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

DE CASTRO, JOSEPH L., September, 1911.
Assistant Superintendent, Consolidated Gas Company, foot of East 115th Street, New York, New York.

DEFREITAS, WILLIAM, March, 1910.
Assistant Superintendent, General Fuel Appliance Department, Consolidated Gas Company, 130 East 15th Street, New York, New York.

DELL, JOHN, October, 1906.
President, Missouri Fire Brick Company, 411 Olive Street, St. Louis, Missouri.

DELONG, JAMES C., September, 1908.
President, Syracuse Lighting Company, 335 South Warren Street, Syracuse, New York.

DE VOE, FREDERICK R., March, 1913.
Secretary and Treasurer, Northern Union Gas Company, 1815 Webster Avenue, Bronx, New York, New York.

DEWEY, V. F., October, 1906.
General Manager, Detroit City Gas Company, Gas Office Building, Detroit, Michigan.

DEXTER, MACDOUGALD, October, 1906.
Superintendent, Gas Light Company of Columbus, 1151 Broad Street, Columbus, Georgia.

DICKEY, CHARLES H., October, 1906.
Charles H. Dickey & Company, Baltimore, Maryland.

DICKEY, E. D. V., March, 1909.
Manager, Freeport Gas Company, 156 Stephenson Street, Freeport, Illinois.

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DICKEY, SAMUEL J., March, 1908.
Engineer, Gas Department, Syracuse Lighting Company, 335 South Warren Street, Syracuse, New York.

DIETERLE, EDWARD A., March, 1908.
Chemist, Seattle Lighting Company, Seattle, Washington.

DILLON, HARRY J., September, 1911.
Superintendent, Brooklyn Borough Gas Company, Coney Island, New York.

DIXON, J. ALFRED, October, 1906.
Vice-President and Manager, Pintsch Compressing Company, 2 Rector Street, New York, New York.

DIXON, R. M., October, 1906.
Vice-President, Pintsch Compressing Company, 2 Rector Street, New York, New York.

DOANE, GEORGE W., September, 1910.
President, New Amsterdam Gas Company, 22 East 22d Street, New York, New York.

DODD, WILLIAM S., October, 1906.
Assistant Treasurer, Laclede Gas Light Company, 11th and Olive Streets, St. Louis, Missouri.

DOHERTY, HENRY L., October, 1906.
Chairman of Board, Denver Gas & Electric Light Company, 60 Wall Street, New York, New York.

DOLE, WALTER S., October, 1906.
Consulting Engineer, Santa Monica Water Company, 1400 Second Street, Santa Monica, California.

DOLLEY, GEORGE M., October, 1906.
Manager, Indiana Lighting Company, Logansport, Indiana.

DONAHUE, E. J., October, 1906.
Engineer, Hudson Division, Public Service Gas Company, St. Paul and St. James Avenues, Jersey City, New Jersey.

DORNER, WILLIAM F., October, 1906.
Superintendent, 25th Ward Gas Works, United Gas Improvement Company, Richmond and Tioga Streets, Philadelphia, Pennsylvania.

DORR, WILLIAM J., September, 1907.
Superintendent of Gas Distribution, Los Angeles Gas & Electric Corporation, 645 South Hill Street, Los Angeles, California.

DOTY, PAUL, October, 1906.
Vice-President and General Manager, St. Paul Gas Light Company, 159 East Sixth Street, St. Paul, Minnesota.

DOUGHERTY, BENJAMIN R., October, 1906.
Superintendent, Richmond Water & Light Company, Richmond, Kentucky.

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DOUGLAS, HENRY W., October, 1906.
Manager, Ann Arbor Gas Company, 211 East Huron Street, Ann Arbor, Michigan.

DOUGLAS, JAMES B., September, 1909.
Manager, Claim Department, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

DOUTHIRT, W. F., October, 1906.
Fourth Vice-President, The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

DOWN, FREDERICK J., March, 1910.
Superintendent, 42d Street Station, Consolidated Gas Company, Foot West 42d Street, New York, New York.

DOWNEY, JAMES N., September, 1907.
Assistant Superintendent, Camden Coke Company, Camden, New Jersey.

DUDLEY, A. D., March, 1908.
New Business Agent, Syracuse Lighting Company, Syracuse, New York.

DUGGAN, FRANK P., March, 1911.
Superintendent, Gas Department, Penn Central Light & Power Company, 31 West Market Street, Lewistown, Pennsylvania.

DUNBAR, C. H., March, 1909.
Post Office Box 517, Elgin, Illinois.

DUNBAR, JAMES W., October, 1906.
Superintendent, United Gas & Electric Company, 138 E. Spring Street, New Albany, Indiana.

DUNCAN, RONALD BRUCE, September, 1911.
Superintendent, Spring Garden District, United Gas Improvement Company, 1615 North 9th Street, Philadelphia, Pennsylvania.

DUNN, F. S., October, 1906.
Engineer, Municipal Gas Company, 1131 Broadway, Albany, New York.

DUNNE, PHILIP, October, 1906.
Night Superintendent, Consolidated Gas Company of New York, 558 West 170th Street, New York, New York.

DURKEE, CHARLES C., September, 1909.
Superintendent, Pueblo Gas & Fuel Company, 811 West 18th Street, Pueblo, Colorado.

DUSENBERRY, JAMES P., September, 1907.
Treasurer, Public Service Gas Company, 763 Broad Street, Newark, New Jersey.

DUSTIN, GUY K., October, 1906.
48 Macon Street, Brooklyn, N. Y.

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DUTTER, H. O., October, 1906.
Manager, Bucyrus Telephone Company, Bucyrus, Ohio.

DUTTON, LEWIS R., October, 1906.
Division Manager, Jenkintown District, Philadelphia Suburban Gas & Electric Company, Wyncote, Pennsylvania.

DUTTON, R. H., October, 1906.
19 West Union Street, West Chester, Pennsylvania.

EARNSHAW, EDWARD H., October, 1906.
Assistant General Manager, Public Service Gas Company, 759 Broad Street, Newark, New Jersey.

EATON, ALFRED B., October, 1906.
Vice-President, Sheboygan Gas Light Company, 1519 Peoples Gas Building, Chicago, Illinois.

EATON, HOMER M., March, 1910.
Manager, Flint Gas Company, Flint, Michigan.

EATON, JAMES B., March, 1907.
Purchasing Agent, Rochester Railway & Light Company, 34 Clinton Avenue, North, Rochester, New York.

EATON, W. M., October, 1906.
Director, Michigan Light Company, Hodenpyl, Hardy & Company, 1128 Fourth Street, Jackson, Michigan.

EAVENSON, WILLIAM K., October, 1906.
Special Representative, Industrial Gas Appliance Laboratory, Consolidated Gas Company, 376 2d Avenue, New York, New York.

EGNER, FREDERIC, October, 1906.
General Consulting Gas Engineer, 516 Quincy Street, N. W., Washington, District of Columbia.

EILBECK, A. B., October, 1906.
With H. L. Doherty & Company, 60 Wall Street, New York, New York.

EINSTEIN, A. C., March, 1908.
Vice-President and General Manager, St. Louis County Gas Company, 315 North 12th Street, St. Louis, Missouri.

ELBERT, V. L., October, 1906.
General Manager, St. Joseph Gas Company, 8th and Francis Streets, St. Joseph, Missouri.

ELDER, DAVID, September, 1907.
Assistant Superintendent, Coal Products Manufacturing Company, 215 Cass Street, Joliet, Illinois.

ELLIOTT, ARTHUR H., October, 1906.
Consulting Engineer-Chemist, Consolidated Gas Company of New York, 49 Whitestone Avenue, Flushing, New York.

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ELLIOTT, LARUE B., September, 1908.
Division Superintendent, North Division Street Department, Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

ELLIS, HARRY, September, 1907.
Superintendent of Distribution, Public Service Gas Company, Front and Cherry Streets, Camden, New Jersey.

ELLIS, JOHN W., October, 1906.
President and Manager, Providence Gas Company, 20 Market Square, Providence, Rhode Island.

ELSTON, I. C., JR., October, 1906.
Elston, Clifford & Company, 707 New York Life Building, 39 South LaSalle Street, Chicago, Illinois.

ELY, FRANKLIN J., March, 1908.
Purchasing Agent, Peoples Gas Light & Coke Company, Peoples Gas Building, Chicago, Illinois.

ELY, SETH HARRISON, March, 1908.
General Manager, Dover, Rockaway & Port Oram Gas Company, 62 Richards Avenue, Dover, New Jersey.

ENGEL, FRANCIS, October, 1906.
Superintendent, Elizabethtown Gas Light Company, Elizabeth, New Jersey.

ENGLISH, A. L., October, 1906.
Manager, Citizens Gas & Electric Company, 26 Pearl Street, Council Bluffs, Iowa.

ENRIGHT, J. H., October, 1906.
Manager, Frederick Gas & Electric Company, Frederick, Maryland.

ESTBERG, HOWARD C., September, 1911.
Manager, Greeley Gas & Fuel Company, Greeley, Colorado.

EUSTACE, E. W., October, 1906.
With Key City Gas Company, Dubuque, Iowa.

EUSTACE, JOHN H., October, 1906.
Engineer, Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

EVANS, CHARLES D., March, 1911.
Division Superintendent, Philadelphia Company, 435 6th Avenue, Pittsburgh, Pennsylvania.

EVANS, CHARLES H., October, 1906.
Consulting and Contracting Engineer, 538 Postal Telegraph Building, Chicago, Illinois.

EVANS, GEORGE B., October, 1906.
Laclede Gas Light Company, 11th and Olive Streets, St. Louis, Missouri.

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EVANS, OWEN BROOKE, September, 1907.
Superintendent, Experimental Plant, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

EVES, PHILMER, September, 1907.
Sales Agent, The Indianapolis Gas Company, 49 South Pennsylvania Street, Indianapolis, Indiana.

EWING, ALONZO PRENTISS, March, 1913.
Assistant General Manager, Detroit City Gas Company, Gas Office Building, Detroit, Michigan.

EYMAN, CHARLES M., March, 1912.
Manager, Boise Gas Light & Coke Company, Boise, Idaho.

EYSENBACH, E. E., October, 1906.
General Manager, San Antonio Gas & Electric Company, San Antonio, Texas.

FAIR, CAMPBELL W., October, 1906.
President and Manager, Webster City Gas Company, Webster City, Iowa.

FANCHER, NATHANIEL C., March, 1910.
Superintendent of Manufacture, Seattle Lighting Company, Seattle, Washington.

FARR, ALBERT L., October, 1906.
Engineering Department, Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

FERGUSON, B. B., October, 1906.
Superintendent, Portsmouth Gas Company, Box 39, Portsmouth, Virginia.

FERRIER, JAMES, October, 1906.
President, Rome Municipal Gas Company, 420 Broad Street, Rome, Georgia.

FERRIS, H. H., October, 1906.
Engineer of Manufacture, Public Service Gas Company, 446 Market Street, Newark, New Jersey.

FIELD, ROY ALBRIGHT, October, 1906.
Vice-President and General Manager, Kentucky Public Service Company, Inc., Hopkinsville, Kentucky.

FISHER, DAVID G., October, 1906.
Superintendent, Central Illinois Light Company, 316 South Jefferson Street, Peoria, Illinois.

FISHER, HOWELL, March, 1911.
Assistant Superintendent, New England Gas & Coke Company, Everett, Massachusetts.

FITZ, ROBERT F., October, 1906.
Consulting Engineer, Post Office Box 275, Los Angeles, California.

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FITZGERALD, LEONARD, October, 1906.
Superintendent, Gas & Electric Department, Gary Heat, Light & Water Company, Broad and Fifth Avenue, Gary, Indiana.

FLOOK, WILLIAM M., March, 1908.
Assistant Secretary, Peoples Gas Light & Coke Company of Chicago, Illinois, 54 Wall Street, New York, New York.

FLOWERS, DEAN WILCOX, September, 1907.
General Superintendent, St. Paul Gas Light Company, 6th and Jackson Streets, St. Paul, Minnesota.

FLOYD, JAMES R., October, 1906.
Assistant Treasurer, International Agricultural Corporation, 165 Broadway, New York, New York.

FOGG, OSCAR H., October, 1906.
Engineer of Utilization, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

FOLGER, OLIVER H., September, 1912.
Assistant Superintendent of Distribution, Public Service Gas Company, 40 Columbia Avenue, Passaic, New Jersey.

FOLSOM, ROBERT MORSE, September, 1911.
Second Assistant Superintendent, New England Gas & Coke Company, Everett, Massachusetts.

FORD, A. H., October, 1906.
President, Birmingham Railway, Light & Power Company, Birmingham, Alabama.

FORSTALL, ALFRED E., October, 1906.
Consulting Engineer, Secretary Trustees Gas Educational Fund, 84 William Street, New York, New York.

FORSTALL, WALTON, October, 1906.
Assistant Engineer of Distribution, Philadelphia Gas Works, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

FOSHAY, W. B., September, 1911.
Manager, Northwestern Electric Co., Portland, Oregon.

FOWLER, SAMUEL J., October, 1906.
Treasurer and Agent, Charlestown Gas & Electric Company, 29 Main Street, Charlestown, Massachusetts.

FOX, CLIFFORD S., October, 1906.
Superintendent, East River Gas Company, Webster Avenue and East River, Long Island City, New York.

FRANCIS, J. EDWARD, September, 1912.
Superintendent, Suffolk Gas-Electric Company, Suffolk, Virginia.

FRANCKLYN, CHARLES G., March, 1911.
General Agent, Central Union Gas Company, 519 Courtlandt Avenue, New York, New York.

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FRANCKLYN, GILBERT, March, 1909.
Engineer of Distribution, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

FRANZINI, JOSEPH BERNARD, September, 1910.
Superintendent, Gas Distribution Department, San Antonio Gas & Electric Company, 305 East Houston Street, San Antonio, Texas.

FRAZER, D. N., October, 1906.
Treasurer and General Manager, Battle Creek Gas Company, 26 East Main Street, Battle Creek, Michigan.

FREEMAN, FREDERICK CHARLES, September, 1910.
Engineer, The United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

FREESE, FRED. W., October, 1906.
Gas Engineer, Fort Wayne, Indiana.

FRENCH, CHARLES S., September, 1910.
Secretary and Treasurer, Galveston Gas Company, Galveston, Texas.

FRICK, JOHN A., October, 1906.
Superintendent, Allentown Gas Company, 516 Hamilton Street, Allentown, Pennsylvania.

FRUEAUFF, FRANK W., October, 1906.
President, Denver Gas & Electric Light Company, H. L. Doherty & Company, 60 Wall Street, New York, New York.

FRUEAUFF, HARRY D., March, 1910.
Treasurer and General Manager, City Light & Traction Company, 404 South Ohio Street, Sedalia, Missouri.

FULWEILER, WALTER HERBERT, September, 1907.
Chemist, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

FURLONG, WILLIAM G., March, 1911.
Office Manager, Municipal Gas Company, 112 State Street, Albany, New York.

GADSDEN, P. H., March, 1911.
President, Charleston Consolidated Railway & Lighting Company, Charleston, South Carolina.

GALLOWAY, EDWARD WILLIAM, March, 1913.
Assistant Engineer, Gas Department, Illinois Northern Utilities Company, Dixon, Illinois.

GALT, JAMES HENRY, September, 1913.
Superintendent of Works and Distribution, Public Service Gas Company, 147 East Hanover Street, Trenton, New Jersey.

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GANNON, JOHN J., October, 1906.
Superintendent and Agent, Vicksburg Gas Company, Post Office Box 258, Vicksburg, Mississippi.

GANSER, HERBERT H., October, 1906.
Manager, Counties Gas & Electric Company, 212 DeKalb Street, Norristown, Pennsylvania.

GANZ, ALBERT FREDERICK, September, 1913.
Consulting Engineer; Professor of Electrical Engineering, Stevens Institute of Technology, Hoboken, New Jersey.

GARTLAND, C. C., October, 1906.
4082 East 76th Street, Cleveland, Ohio.

GARTLEY, WILLIAM H., October, 1906.
Engineer of Philadelphia Gas Works, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

GAVIT, E. P., October, 1906.
Secretary and Treasurer, Municipal Gas Company, 112 State Street, Albany, New York.

GAWTRY, LEWIS B., September, 1908.
Vice-President, Consolidated Gas Company of New York, 70 East 55th Street, New York, New York.

GEFVERT, CHARLES J., September, 1910.
Engineer's Assistant, Consolidated Gas Company, 124 East 15th Street, New York, New York.

GEIST, CARLTON, March, 1912.
General Manager, Atlantic City Gas Co., 2001 Atlantic Avenue, Atlantic City, New Jersey.

GEIST, CLARENCE H., March, 1912.
President, Atlantic City Gas Company, 1127 Land Title Building, Philadelphia, Pennsylvania.

GENAY, THOMAS BERTRAM, October, 1906.
Superintendent of Manufacturing, Des Moines Gas Company, 412 West 7th Street, Des Moines, Iowa.

GENAY, THOMAS S., October, 1906.
Chief Clerk, Second Vice-President's Department, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

GENTRY, R. GARLAND, October, 1906.
General Salesman, Denver Gas & Electric Company, 900 15th Street, Denver, Colorado.

GERDENIER, C. M., March, 1909.
Superintendent, Bridgeport Gas Light Company, 174 Arch Street, Bridgeport, Connecticut.

GEROULD, CHARLES L., October, 1906.
Care of E. H. Bliss, Pepperell, Massachusetts.

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GIBBONS, P. H., October, 1906.
Northern Liberties Gas Co., 935 North 48th Street, Philadelphia, Pennsylvania.

GIFFORD, N. W., October, 1906.
General Manager, East Boston Gas Company, 26 Central Square, East Boston, Massachusetts.

GILLETT, MELVILLE, October, 1906.
Director, Gas Companies, Newark, Ohio.

GILLINGHAM, HUBERT D., October, 1906.
Assistant Sales Manager, Public Service Gas Company, 759 Broad Street, Newark, New Jersey.

GILPIN, FRANCIS HOPKINSON, September, 1907.
Gas Engineer, United Gas Improvement Company, 3101 Passyunk Avenue, Philadelphia, Pennsylvania.

GINLEY, JOHN, September, 1908.
Superintendent, Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

GLASGOW, ARTHUR GRAHAM, October, 1906.
Humphreys & Glasgow, 36 Victoria Street, London, S. W., England.

GLASS, SHELDON J., October, 1906.
Vice-President, Milwaukee Gas Light Company, 182 Wisconsin Street, Milwaukee, Wisconsin.

GOLDEN, JOHN W., October, 1906.
Vice-President, Savannah Gas Company, 9 Congress Street, West, Savannah, Georgia.

GOODNOW, GEORGE F., October, 1906.
General Manager, North Shore Gas Company, Waukegan, Illinois.

GORDON, LEROY O., March, 1913.
Manager, Valparaiso Lighting Company, 152 West Main Street, Valparaiso, Indiana.

GOUDY, W. R., October, 1906.
With Williamson & Mead, 79 Wall Street, New York, New York.

GOULD, JOHN A., October, 1906.
Engineer of Distribution, Boston Consolidated Gas Company, 24 West Street, Boston, Massachusetts.

GOULD, VERNON K., October, 1906.
Milo, Maine.

GRAEFF, HAROLD W., October, 1906.
1513 North Thirty-third Street, Philadelphia, Pennsylvania.

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GRAF, CARL H., October, 1906.
General Manager, The Indianapolis Gas Company, Broadway and 13th Street, Indianapolis, Indiana.

GRAHAM, ALLAN S., September, 1908.
Superintendent, Gas Department, Northern Indiana Gas & Electric Company, Hammond, Indiana.

GRAHAM, MALCOLM M., October, 1906.
Secretary and Treasurer, New Amsterdam Gas Company, 22 East Twenty-second Street, New York, New York.

GRANT, ROBERT, September, 1907.
Treasurer, Boston Consolidated Gas Company, 24 West Street, Boston, Massachusetts.

GREACEN, W., JR., September, 1907.
Agent, Public Service Gas Company, 538 Washington Street, Hoboken New Jersey.

GREY, JOHN CHESTER, September, 1908.
Superintendent, Savannah Gas Company, 9 Congress Street, West, Savannah, Georgia.

GRIBBEL, JOHN, October, 1906.
President, Tampa (Florida) Gas Company, 1513 Race Street, Philadelphia, Pennsylvania.

GRIFFIN, JOHN F., March, 1907.
Manager, Oskaloosa Light & Power Company, 216 High Avenue, West, Oskaloosa, Iowa.

GRISWOLD, R. G., October, 1906.
Gas Engineer, with H. L. Doherty & Company, 60 Wall Street, New York, New York.

GRUBER, CHARLES A., September, 1912.
Manager, Saranac Lake Gas Company, 20 Main Street, Saranac Lake, New York.

GUFFEY, JOSEPH F., October, 1906.
General Manager, The Philadelphia Company, 435 Sixth Avenue, Pittsburgh, Pennsylvania.

GULDLIN, OLAF N., October, 1906.
President, Western Gas Construction Company, 2306 Fairfield Avenue, Fort Wayne, Indiana.

HAAG, F. E., March, 1909.
Auditor, Williamsport (Pa.) Gas Company, H. D. Walbridge & Company, 14 Wall Street, New York, New York.

HAASE, EWALD, October, 1906.
Secretary and Treasurer, Milwaukee Gas Light Company, 182 Wisconsin Street, Milwaukee, Wisconsin.

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HACKSTAFF, JOHN DUDLEY, September, 1913.
Consulting Engineer, Harwich Port, Massachusetts.

HADDOCK, ISAAC T., September, 1913.
Chemist for Cambridge Gas Light Company, 354 Third Street, East Cambridge, Massachusetts.

HAFTENKAMP, JOSEPH P., September, 1907.
Assistant Superintendent, Rochester Railway & Light Company, 34 Clinton Avenue, North, Rochester, New York.

HAIGHT, THEODORE, March, 1911.
Superintendent, Equity Works, Brooklyn Union Gas Company, Foot North 12th Street, Brooklyn, New York.

HAINES, JANSEN, October, 1906.
Manager, Des Moines Gas Company, 412 West 7th Street, Des Moines, Iowa.

HALL, A. H., October, 1906.
Assistant Secretary and Superintendent of Distribution, Central Union Gas Company, 519 Courtlandt Avenue, New York, New York.

HALL, ELMON L., September, 1912.
Chief Engineer, Portland Gas & Coke Company, 506½ Weidler Street, Portland, Oregon.

HALSEY, WILLIAM M., March, 1909.
Chief Clerk, Public Service Gas Company, Gas and Electric Departments, 759 Broad Street, Newark, New Jersey.

HAMMATT, CLARENCE S., October, 1906.
Consulting Engineer, 1943 Main Street, Jacksonville, Florida.

HAMMON, WILLIAM H., October, 1906.
President, Hope Engineering & Supply Company, 902 Farmers Bank Building, Pittsburgh, Pennsylvania.

HAMMOND, WILBER M. R., March, 1912.
Comptroller, New York & Richmond Gas Company, 694 Bay Street, Stapleton, Staten Island, New York.

HANLAN, J. P., September, 1907.
Agent, New Business Department, Public Service Gas Company, Post Office Box 590, Newark, New Jersey.

HANTZMON, H. M., October, 1906.
Superintendent, City Gas Department, Charlotteville, Virginia.

HARDICK, CHARLES F., October, 1906.
District Superintendent and Agent, United Gas Improvement Company, 5961 Ridge Avenue, Philadelphia, Pennsylvania.

HARE, C. WILLING, September, 1908.
Manager, New Business Department, The United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

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HARE, JOSEPH B., March, 1913.
Assistant Superintendent, Mains and Services, Central Union Gas Company, 519 Courtlandt Avenue, New York, New York.

HARGREAVES, ROBERT H., September, 1912.
Superintendent, San Jose Gas Works, Pacific Gas & Electric Company, Second and Antonio Streets, San Jose, California.

HARLOW, JUSTIN EDWARDS, March, 1913.
Construction Engineer, Illinois Northern Utilities Company, 806 3rd Street, Dixon, Illinois.

HARPER, ROBERT BRINTON, March, 1908.
Superintendent of Testing Laboratories, Peoples Gas Light and Coke Company, 2501 Salt Street, Chicago, Illinois.

HARRIES, GEORGE HERBERT, September, 1912.
President, Louisville Gas & Electric Company, 311 West Chestnut Street, Louisville, Kentucky.

HARRIMAN, HORACE MARSHALL, March, 1908.
General Superintendent, New Orleans Gas Light Company, 201 Baronne Street, New Orleans, Louisiana.

HARRINGTON, A. S., October, 1906.
Superintendent of Construction, Peoples Gas Light & Coke Company, Division Street and Elston Avenue, Chicago, Illinois.

HARRINGTON, WALTER K., September, 1908.
Manager, The American Meter Company, 11th Avenue and 47th Street, New York, New York.

HARRISON, GEORGE MORTON, March, 1908.
Special work on replacement valuations of gas plants; Engineer, Sioux City Gas & Electric Company, Sioux City, Iowa.

HARROP, H. B., DR., October, 1906.
Manager, Société Anonymé du Gaz, Rio de Janeiro, Brazil.

HART, JULIAN G., September, 1912.
Assistant Engineer, Public Service Company of Northern Illinois, 137 South La Salle Street, Chicago, Illinois.

HARTMAN, WILLIAM E., October, 1906.
Consulting Engineer, 4923 Sheridan Road, Chicago, Illinois.

HARTZELL, A. C., October, 1906.
Treasurer, Greenville Natural Gas Company, Canal Street, Greenville, Pennsylvania.

HASTINGS, FRANK S., March, 1908.
President, Indianapolis Gas Company, 80 Broadway, New York, New York.

HATHAWAY, E. C., October, 1906.
Vice-President and General Manager, City Gas Company of Norfolk, 82 Plume Street, Norfolk, Virginia.

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HAWTHORNE, WILLIAM JAMES, September, 1908.
Superintendent, Consolidated Gas Company, Foot West 44th Street Station, New York, New York.

HAYES, CLIFTON R., September, 1912.
Manager, Fitchburg Gas & Electric Light Company, 256 Main Street, Fitchburg, Massachusetts.

HEDGES, WILLIAM C., October, 1906.
Secretary and Superintendent, Mansfield Gas Light Company, Mansfield, Ohio.

HELLEN, FRANK, March, 1907.
Superintendent, Gas Distribution Department, Rochester Railway & Light Company, 34 Clinton Avenue, North, Rochester, New York.

HELLEN, JOHN, October, 1906.
Superintendent of Distribution, Grand Rapids Gas Light Company, 109 North Ottawa Street, Grand Rapids, Michigan.

HELME, WILLIAM E., October, 1906.
Director several Gas Companies, 1339 Cherry Street, Philadelphia, Pennsylvania.

HELPS, GEORGE, September, 1913.
Civil Engineer, Engineer and Manager, Nuneaton Gas Company, Nuneaton, England.

HEMMINGER, GEORGE REVERDEY, September, 1908.
Engineer with The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

HENDERSON, SAMUEL W., September, 1912.
Vice-President and General Manager, Water, Gas & Electric Company, Excelsior Springs, Missouri.

HENDERSON, WILLIAM M., September, 1912.
Assistant Gas Engineer, Pacific Gas & Electric Company, Oakland, California.

HENOFER, J. P., March, 1909.
Superintendent, Hoboken Gas Works, Hudson Division, Public Service Gas Company, Halladay and Forest Streets, Jersey City, New Jersey.

HERING, EDWARD, March, 1913.
Engineer's Assistant, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

HEWITT, ARTHUR, September, 1910.
General Manager, Consumers Gas Company, 19 Toronto Street, Toronto, Ontario, Canada.

HILLEMEYER, JOSEPH E., March, 1910.
Engineer, St. Louis County Gas Company, Lockwood and McClure Avenues, Webster Groves, Missouri.

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HINE, WILLARD FOSTER, September, 1911.
Chief Gas Engineer, Public Service Commission for the First District, 154 Nassau Street, New York, New York.

HINMAN, CHARLES W., October, 1906.
Chemical Engineer, Winchester, Massachusetts.

HINTZE, THOMAS F., September, 1913.
Engineer's Assistant, Consolidated Gas Company, 124 East 15th street, New York, New York.

HIRAMATSU, SUYEKUCHI, October, 1906.
Chief Engineer, Tokio Gas Company, Nishikicho, Kanda, Tokio, Japan.

HIRST, HOMER T., JR., September, 1910.
Assistant Superintendent, North Division, Peoples Gas Light & Coke Company, 634 Hobbie Street, Chicago, Illinois.

HIRST, JESSE BOWMAN, September, 1910.
Superintendent of Pressures, Peoples Gas Light & Coke Company, Peoples Gas Building, Chicago, Illinois.

HODGES, C. H., March, 1909.
Assistant Superintendent, Consolidated Gas Company of New York, 501 East 21st Street, New York, New York.

HODGSON, JOSEPH ERNEST, March, 1911.
Manager, Fulton County Gas & Electric Company, 18 East Fulton Street, Gloversville, New York.

HOFFMAN, HOWARD, October, 1906.
Superintendent, Gas Department, Counties Gas & Electric Company, Ardmore, Pennsylvania.

HOFMANN, G. MAX, October, 1906.
General Superintendent, Fort Wayne Gas Company, Fort Wayne, Indiana.

HOFMANN, LOTHAR, October, 1906.
Assistant Engineer, Fort Wayne Gas Company, 2205 Broadway, Fort Wayne, Indiana.

HOLDEN, THOMAS F., October, 1906.
Superintendent of Works, Georgetown Gas Light Company, 218 Eighth Street, S. W., Washington, District of Columbia.

HOLMAN, C. L., October, 1906.
President and General Manager, The Laclede Gas Light Company, 11th and Olive Streets, St. Louis, Missouri.

HOLZER, EDWIN G., October, 1906.
Superintendent, Easton Gas & Electric Company, 349 Bushkill Street, Easton, Pennsylvania.

HONE, FREDERIC DEP., September, 1911.
Consulting Engineer, 1 Liberty Street, New York, New York.

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HORNING, GEORGE R., September, 1908.
Manager, Macon Gas Company, Macon, Georgia.

HOUGH, DAVID LEAVITT, October, 1906.
President, United Engineering & Contracting Company, 17 West 42d Street, New York, New York.

HOUGHTON, CHARLES P., September, 1910.
Second Vice-President, Los Angeles Gas & Electric Corporation, 645 South Hill Street, Los Angeles, California.

HOWARD, ABRAM C., October, 1906.
Gas Engineer, United Gas & Electric Corporation, 40 Wall Street, New York, New York.

HOWARD, CHARLES A., September, 1906.
President, Aberdeen Gas Company, Aberdeen, South Dakota.

HOWLAND, LEWIS A., March, 1910.
General Superintendent, Queens Borough Gas & Electric Company, Far Rockaway, New York.

HOY, CHAS. W., March, 1908.
Manager, New Jersey Gas Company, Glassboro, New Jersey.

HOYT, HARRY B., October, 1906.
General Manager, Jacksonville Gas Company, Church and Laura Streets, Jacksonville, Florida.

HOYT, WILLIAM G., October, 1906.
President, The Standard Gas Light Company, 1328 Broadway, New York, New York.

HUBER, FRANK, October, 1906.
Manufacturing Superintendent, Louisville Gas & Electric Company, Jackson and Washington Streets, Louisville, Kentucky.

HUDDLE, WILEY JEROME, March, 1913.
Consulting Gas Engineer, Commission of Wisconsin, 636 East Gorham Street, Madison, Wisconsin.

HUDSON, DARWIN S., March, 1909.
Field Engineer, Astoria Light, Heat & Power Company, Astoria, Long Island, New York.

HUESTIS, LEON DAVID, March, 1909.
Superintendent of Construction, Philadelphia Suburban Gas & Electric Company, 912 Highland Avenue, Chester, Pennsylvania.

HULSWIT, FRANK T., October, 1906.
Director Several Gas Companies, Child, Hulswit & Company, 411 Michigan Trust Building, Grand Rapids, Michigan.

HULSWIT, JOHN A., March, 1912.
Treasurer, Grand Rapids Gas Light Company, Pearl and Ottawa Streets, Grand Rapids, Michigan.

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HUMPHREYS, ALEXANDER C., October, 1906.
President, Buffalo (N. Y.) Gas Company, and President, Humphreys & Miller, 165 Broadway, New York, New York.

HUMPHREYS, C. J. R., October, 1906.
Vice-President and Agent, Lawrence Gas Company, 370 Essex Street, Lawrence, Massachusetts.

HUMPHREYS, FRANK WILDER, March, 1911.
In charge Gas Appliance Display Rooms, Consolidated Gas Company, 30 East 42d Street, New York, New York.

HUMPHREYS, J. J., October, 1906.
Engineer and General Manager, Louisville Gas Company, 311 West Chestnut Street, Louisville, Kentucky.

HUMPHRYS, HENRY M., October, 1906.
Superintendent, West Side Works, Milwaukee Gas Light Company, 182 Wisconsin Street, Milwaukee, Wisconsin.

HUNT, H. R., October, 1906.
Division Superintendent, Peoples Gas Light & Coke Company, 25th and Loomis Streets, Chicago, Illinois.

HUNTER, CHARLES WESLEY, September, 1910.
Vice-President and General Manager, Ocala Gas Company, Ocala, Florida.

HUNTER, CHAS. W., September, 1909.
Gas Engineer, with Stone & Webster Engineering Corporation, 147 Milk Street, Boston, Massachusetts.

HUNTER, J. F., March, 1909.
Assistant Engineer of Construction, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

HURLBURT, A., October 1906.
Engineer, Kansas City Gas Company, 910 Grand Avenue, Kansas City, Missouri.

HUTCHINGS, JAMES T., September, 1907.
General Manager, Rochester Railway & Light Company, 34 Clinton Avenue, North, Rochester, New York.

HUTCHINSON, FRANK R., October, 1906.
Care of East Ohio Gas Company, 621 Superior Avenue, N. E., Cleveland Ohio.

HYDE, EDWARD BOLTON, September, 1911.
Superintendent, Commercial Department, New Amsterdam Gas Company, 22 East 22d Street, New York, New York.

HYDE, HENRY H., October, 1906.
Engineer, Belt Gas Company, Deadwood, South Dakota.

IKENA, FREDERICK J., September, 1912.
Superintendent of Works, Municipal Gas Company, 1131 Broadway, Albany, New York.

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IVES, HERBERT E., March, 1913.
Physicist, The United Gas Improvement Company, 3101 Passyunk Avenue, Philadelphia, Pennsylvania.

JACOBSON, ERNEST, September, 1910.
Superintendent of Manufacture, Northwestern Gas Light & Power Company, 115 Oak Park Avenue, Oak Park, Illinois.

JACKSON, THOMAS H., March, 1910.
General Agent, Philadelphia Gas Works, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

JACKSON, WILLIAM B., October, 1906.
Consulting Engineer, 111 West Monroe Street, Chicago, Illinois.

JAMES, F. M., October, 1906.
General Accountant, Western United Gas & Electric Company, Aurora, Illinois.

JAMES, ROBERT C., September, 1907.
General Auditor, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

JARDINE, DAVID WILLIAM, September, 1913.
Assistant Manager, Burlington Light & Power Company, Burlington, Vermont.

JAYNE, RALPH A., March, 1913.
Superintendent of Distribution, Detroit City Gas Company, Gas Office Building, Detroit, Michigan.

JELLIFFE, C. N., October, 1906.
Secretary and Treasurer, American Light & Traction Company, 40 Wall Street, New York, New York.

JENKS, R. J., October, 1906.
Superintendent, Northwestern Gas Light & Coke Company, 1408 Benson Avenue, Evanston, Illinois.

JENNINGS, ROBT. J., October, 1906.
Superintendent, Pelham Works, Westchester Lighting Company, Mt. Vernon, N. Y.

JOHNSON, ADOLPH C., September, 1913.
Assistant Superintendent, Consolidated Gas Company, 112 West 42d Street, New York, New York.

JOHNSON, GUY MAXWELL, September, 1912.
Engineer, Nashville Gas & Heating Company, 611 Church Street, Nashville, Tennessee.

JOHNSON, HERBERT GILMORE, October, 1906.
Superintendent of Manufacture, Utica Gas & Electric Company, 222 Genesee Street, Utica, New York.

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JOHNSON, OLE SEAHOLM, September, 1913.
Main Foreman, St. Paul Gas Light & Coke Company, 6th and Jackson Streets, St. Paul, Minnesota.

JOHNSTON, MERVYN E., October, 1906.
Assistant Secretary and Assistant Treasurer, Ogden Gas Company, The Linde Air Products Company, 42d Street Building, New York, New York.

JONES, ARTHUR O., September, 1912.
Engineer, 71 Himley Road, Dudley, Worcestershire, England.

JONES, EDWARD C., October, 1906.
Chief Engineer, Gas Department, Pacific Gas & Electric Company, 445 Sutter Street, San Francisco, California.

JONES, EDWIN DUBOSE, March, 1913.
General Foreman, Assistant to Superintendent, Brooklyn Union Gas Company, 5th and Hoyt Streets, Brooklyn, New York.

JONES, EDWIN PEIRCE, September, 1912.
Superintendent, with United Gas Improvement Company, 1943 South Cecil Street, Philadelphia, Pennsylvania.

JONES, HENRY HARRISON, September, 1912.
Vice-President and Manager, San Diego Consolidated Gas & Electric Company, San Diego, California.

JONES, PAUL R., March, 1908.
Auditor, Henry L. Doherty & Company, 60 Wall Street, New York, New York.

JONES, THOMAS CLIVE, October, 1906.
President, Delaware Gas Company, 6 West Winter Street, Delaware, Ohio.

JONES, THOMAS J., March, 1907.
With The Columbus Gas & Fuel Company, 135 North Front Street, Columbus, Ohio.

JOURDAN, EDWARD R., October, 1906.
General Superintendent of Mains and Services, Consolidated Gas Company, 124 East 15th Street, New York, New York.

JOURDAN, JAMES H., October, 1906.
Vice-President and Chief Engineer, Brooklyn Union Gas Company, 180 Remsen Street, Brooklyn, New York.

KAHN, SAMUEL, March, 1910.
General Manager, Tacoma Gas Company, Tacoma, Washington.

KALTWASSER, CHARLES M., March, 1913.
General Manager, Lockport Light, Heat & Power Company, Lockport, New York.

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KANE, JOSEPH P., March, 1907.
Superintendent, Westchester Lighting Company, 130 North Main Street, Port Chester, New York.

KEAL, GEORGE I., September, 1911.
Superintendent of Construction, Detroit City Gas Company, Gas Office Building, Detroit, Michigan.

KEEGAN, CHAS. F., September, 1908.
Superintendent, 21st Street Station, Consolidated Gas Company of New York, 501 East 21st Street, New York, New York.

KEENE, ALFRED M., October, 1906.
Comptroller, Westchester Lighting Company, 1st Avenue and 1st Street, Mount Vernon, New York.

KEILLOR, JOHN, March, 1907.
Dominion Tar & Ammonia Company, Ltd., 220 Lister Building, Hamilton, Ontario, Canada.

KELLER, C. M., October, 1906.
Director, Gas Company, 312 Washington Street, Columbus, Indiana.

KELLEY, WILLIAM D., September, 1912.
General Superintendent of Meters, Consolidated Gas Company, 124 East 15th Street, New York City.

KELLOGG, LEONARD L., October, 1906.
President and Manager, Sioux City Gas & Electric Company, 511 Pierce Street, Sioux City, Iowa.

KELLOGG, RAYMOND C., March, 1909.
Assistant to Superintendent of Street Department, Brooklyn Union Gas Company, 5 Skillman Street, Brooklyn, New York.

KELLOGG, R. M., October, 1906.
Engineer with Westchester Lighting Company, Mount Vernon, New York.

KELSEY, CHARLES B., September, 1912.
President, American Utilities Company, Grand Rapids, Michigan.

KENAN, NORMAN G., October, 1906.
President, The Union Gas & Electric Company, 3416 Brookline Avenue, Cincinnati, Ohio.

KENDALL, ALBERT WHITTEMORE, March, 1910.
Assistant Manager, Rockford Gas Light & Coke Company, 201 Mulberry Street, Rockford, Illinois.

KENNEDY, JAMES, September, 1907.
Agent, Gas and Electric Departments, Public Service Gas Company, 591 Spring Street, West Hoboken, New Jersey.

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KENNEDY, JAMES S., October, 1906.
Superintendent, Standard Gas Light Company, foot of East 115th Street, New York, New York.

KENNEDY, JOHN PENDLETON, September, 1907.
General Superintendent, Cambridge Gas Light Company, 354 Third Street, East Cambridge, Massachusetts.

KENNEDY, THOMAS P., March, 1911.
Assistant to Superintendent of Street Department, Brooklyn Union Gas Company, 5th and Hoyt Streets, Brooklyn, New York.

KEPPELMAN, JOHN H., October, 1906.
Superintendent, Consumers Gas Company, 20 North Fifth Street, Reading, Pennsylvania.

KEPPELMANN, D. ELLWOOD, October, 1906.
Superintendent of Gas Distribution, Pacific Gas & Electric Company, 445 Sutter Street, San Francisco, California.

KERSTING, ALBERT F., October, 1906.
Superintendent, Mobile Gas Company, Box 234, Mobile, Alabama.

KING, ARTHUR GORDON, September, 1909.
Superintendent's Assistant, Brooklyn Union Gas Company, Nevins and Degraw Streets, Brooklyn, New York.

KINGSBURY, I. C., March, 1909.
Superintendent of Mains, Consolidated Gas Company of New York, 80 Elizabeth Street, New York, New York.

KIRCHER, HARRY B., March, 1907.
514 Church Street, Belleville, Illinois.

KLEIN, AUGUST CLARENCE, September, 1912.
Engineer, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

KLUMPP, JOHN BARTLEMAN, October, 1906
Inspecting Engineer, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

KNAPP, AMOS M., October, 1906.
Foreman of Meter Shop, Westchester Lighting Company, 266 Woodworth Avenue, Yonkers, New York.

KNAPP, ISAAC N., October, 1906.
116 Ardmore Avenue, Ardmore, Pennsylvania.

KNAPP, WILLIAM JARED, March, 1910.
Assistant Superintendent, Division Street Station, Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

KNIGHT, J. J., October, 1906.
Vice-President, Kalamazoo Gas Company, 123 West Street, Kalamazoo, Michigan.

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KNOWLES, WILLIAM P., October, 1906.
Superintendent, Richmond City Gas Works, 2606 Grove Avenue, Richmond, Virginia.

KOHLER, ALBERT J., September, 1913.
Superintendent, Light and Power Department, Lynchburg Traction & Light Company, 523 Main Street, Lynchburg, Virginia.

KOINER, C. W., October, 1906.
General Manager and Engineer, Municipal Lighting Plant, Pasadena, California.

KOWALKE, OTTO L., September, 1909.
Associate Professor Chemical Engineering, Engineering Building, University of Wisconsin, Madison, Wisconsin.

KRAFT, R. P., October, 1906.
Assistant Engineer, Milwaukee Gas Light Company, 182 Wisconsin Street, Milwaukee, Wisconsin.

KRUMREY, ROBERT GARFIELD, September, 1913.
General Superintendent, Beloit Water, Gas & Electric Company, 429 East Grand Avenue, Beloit, Wisconsin.

KUBO, SHOSUKE, September, 1911.
Managing Director of Kobe Gas Company, Ltd., Kobe, Japan.

KUSTER, JOHN D., September, 1912.
Manager San Jose District, Pacific Gas & Electric Company, 2nd and Antonio Streets, San Jose, California.

LAMBERT, EDW. L., September, 1909.
General Manager, Ottumwa Gas Light, Heat & Power Company, Ottumwa, Iowa.

LAMSON, CHARLES DUDLEY, October, 1906.
President and General Manager, Worcester Gas Light Company, 240 Main Street, Worcester, Massachusetts.

LAMSON, WILLIAM O., JR., March, 1907.
Manager, Chester County Gas Company, 33 West Gay Street, West Chester, Pennsylvania.

LANE, FREDERICK K., October, 1906.
Manager and Treasurer, Seattle Lighting Company, Seattle, Washington.

LANE, JAS. M., September, 1909.
Superintendent of Works, Public Service Gas Company, Paterson, New Jersey.

LANE, WILLIAM P., March, 1908.
Superintendent, Point Breeze Works, United Gas Improvement Company, Passyunk Avenue and Schuylkill River, Philadelphia, Pennsylvania.

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LARAWAY, B. R., September, 1908.
Treasurer and General Manager, Jackson Gas Company, Jackson, Michigan.

LATHROP, ALANSON P., October, 1906.
President, American Light & Traction Company, 40 Wall Street, New York, New York.

LAVELLE, WILLIAM J., March, 1913.
Manager Coke Sales, New England Coal & Coke Company, 111 Devonshire Street, Boston, Massachusetts.

LAWLOR, JAS. W., September, 1908.
Superintendent North Station, Peoples Gas Light & Coke Company, 1122 Crosby Street, Chicago, Illinois.

LAWLOR, R. H., October, 1906.
Manager, Indiana Gas Light Company, Noblesville, Indiana.

LAWRENCE, W. F., October, 1906.
General Superintendent, Astoria Light, Heat & Power Company, Long Island City, New York.

LEA, HENRY I., October, 1906.
Consulting Gas Engineer, Peoples Gas Building, Chicago, Illinois.

LEACH, F. A., JR., September, 1912.
Oakland District Manager, Pacific Gas & Electric Company, Post Office Box 426, Oakland, California.

LEARNED, CHARLES A., October, 1906.
General Manager, Meriden Gas Light Company, 33 Colony Street, Meriden, Connecticut.

LEARNED, WALDO A., October, 1906.
General Superintendent, Newton and Watertown Gas Light Company, 308 Washington Street, Newton, Massachusetts.

LEE, FRANCIS V. T., September, 1908.
Care of H. C. Parker, 1601 Taylor Street, San Francisco, California.

LELAND, EDW. D., September, 1909.
Superintendent of Compressing Stations, Philadelphia Company, 4623 Centre Avenue, Pittsburgh, Pennsylvania.

LEONARD, CHARLES F., October, 1906.
Engineer, 220 Broadway, New York, New York.

LETANG, B. E., October, 1906.
Proprietor, Jackson Gas Light Company, Jackson, California.

LEVERING, WM. WALLACE, March, 1908.
Treasurer, Citizens Gas Company of Trenton, Missouri; 1328 Chestnut Street, Philadelphia, Pennsylvania.

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LEWIS, RAYMOND CHAPIN, March, 1911.
Assistant Superintendent of Holder Distribution Department, Brooklyn Union Gas Company, 84 Broadway, Brooklyn, New York.

LEWIS, WILLIAM MORGAN, October, 1906.
Manager, Rockville Gas Company, 7 Park Street, Rockville, Connecticut.

LIGHT, EDWARD H., October, 1906.
Superintendent of Distribution, Dayton Gas Light & Coke Company, 203 East First Street, Dayton, Ohio.

LIGHT, GEORGE, October, 1906.
Superintendent, Dayton Gas Light & Coke Company, 203 East First Street, Dayton, Ohio.

LILLIE, LEWIS, October, 1906.
Third Vice-President and Treasurer, The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

LINDSAY, ROBERT, October, 1906.
Superintendent Gas Department, New Bedford Gas & Edison Light Company, 214 South Water Street, New Bedford, Massachusetts.

LINTON, SAMUEL E., JR., October, 1906.
Superintendent, Sioux Falls Gas Company, Sioux Falls, South Dakota.

LITTLE, ARTHUR DEHON, March, 1908.
Chemical Engineer in General Practice, 93 Broad Street, Boston, Massachusetts.

LITTLE, FRANCIS W., October, 1906.
President, Sault Ste Marie (Mich.) Gas & Electric Company, 1901 Emerson Avenue, South, Minneapolis, Minnesota.

LITTLEHALES, THOMAS, October, 1906.
Garden Hotel, Camden, New Jersey.

LIVINGSTON, H., March, 1909.
Assistant Superintendent Point Breeze Gas Works, The United Gas Improvement Company, Passyunk Avenue and Schuylkill River, Philadelphia, Pennsylvania.

LIVINGSTON, ROBERT E., September, 1911.
Advertising Manager, Consolidated Gas Company, 1 Madison Avenue, New York, New York.

LLOYD, ALFRED G., October, 1906.
Vice-President, Adrian (Mich.) Gas Company, 860 Greenwood Avenue, Detroit, Michigan.

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LLOYD, ERNEST F., October, 1906.
President, Delphos Gas Company, 860 Greenwood Avenue, Detroit, Michigan.

LONG, DAVID SAMUEL, March, 1913.
Meter Department, Gas Company, 218 West Askley Street, Jacksonville, Florida.

LORD, R. S., October, 1906.
Secretary and Treasurer, Hope Engineering & Supply Company, 902 Farmers Bank Building, Pittsburgh, Pennsylvania.

LOVE, EDWARD GURLEY, March, 1913.
Chief Chemist, Consolidated Gas Company, 124 East 15th Street, New York, New York.

LOW, D. W., October, 1906.
Superintendent, Alliance Gas & Electric Company, Alliance, Ohio.

LUCAS, THOMAS J., September, 1911.
Consulting Engineer, Assistant to W. A. Baehr, 2009 Peoples Gas Building, Chicago, Illinois.

LUCENA, JOSEPH, October, 1906.
Superintendent of Distribution, Omaha Gas Company, 1202 Howard Street, Omaha, Nebraska.

LUCKE, CHARLES EDWARD, September, 1913.
Professor, Department of Mechanical Engineering, Columbia University, Morningside Heights, New York, New York.

LUCKENBACH, CHARLES A., September, 1911.
Manager of Construction, Los Angeles Gas & Electric Corporation, 645 South Hill Street, Los Angeles, California.

LUICK, ADOLPH JAMES, September, 1913.
Consulting Engineer with W. A. Baehr, 2009 Peoples Gas Building, Chicago, Illinois.

LUNDBLAD, OSCAR J. A., March, 1911.
Superintendent, Nassau & Suffolk Lighting Company, Main Street, Hempstead, New York.

LUNDGAARD, I., March, 1913.
Industrial Engineer, Rochester Railway & Light Company, 34 Clinton Avenue, North, Rochester, New York.

LUQUEER, ROBERT ORR, October, 1906.
Secretary, Humphreys & Miller, Inc., 165 Broadway, New York, New York.

LUTHER, F. E., October, 1906.
Superinendent, Peoples Gas Light & Coke Company, Michigan Avenue and Adams Street, Chicago, Illinois.

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LUTHER, WILLIAM J., October, 1906.
Superintendent, Attleboro Gas Light Company, 19 Dunham Street, Attleboro, Massachusetts.

LYDECKER, FREDK. ACKERMAN, March, 1913.
Assistant Superintendent of Distribution, Public Service Gas Company, Waverly Place, Madison, New Jersey.

LYNN, JAMES T., October, 1906.
President, National Gas, Electric Light & Power Company, Ford Building. Detroit, Michigan.

LYON, CHAS. LUMSDEN, October, 1906.
Superintendent, St. Augustine Gas & Electric Light Company, St. Augustine, Florida.

LYONS, B. F., October, 1906.
Vice-President and General Manager, Beloit Water, Gas & Electric Company, Beloit, Wisconsin.

MCADAM, BRYCE, October, 1906.
Superintendent of Distribution, Milwaukee Gas Light Company, 406 Bradford Avenue, Milwaukee, Wisconsin.

MCCALLUM, J. N., October, 1906.
Vice-President, Lenawee County Gas & Electric Company, Adrian, Michigan, 39 South La Salle Street, Chicago, Illinois.

MCCARTER, THOS. N., September, 1907.
President, Public Service Gas Company, Broad and Bank Streets, Newark, New Jersey.

MCCARTHY, J. M., March, 1909.
Vice-President, American Light & Traction Company, 40 Wall Street, New York, New York.

MCCLARY, N. A., October, 1906.
President, Northwestern Gas Light Company, 108 La Salle Street, Chicago, Illinois.

MCCLELLAN, WILLIAM, September, 1913.
Consulting Gas Engineer, 141 Broadway, New York, New York.

MCCLELLON, J. M., March, 1911.
Superintendent, New England Gas & Coke Company, Everett, Massachusetts.

MCCLOY, WALTER L., September, 1909.
General Superintendent, Philadelphia Company, 435 Sixth Avenue, Pittsburgh, Pennsylvania.

MCCORKINDALE, WILLIAM J., October, 1906.
General Manager, Wilmington Gas Company, Wilmington, Delaware.

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McCrea, Thomas P., March, 1913.
Assistant Secretary and Treasurer, Los Angeles Gas & Electric Corporation, 645 South Hill Street, Los Angeles, California.

McDonald, Donald, October, 1906.
Vice-President and General Manager, Louisville Gas & Electric Company, 311 West Chestnut Street, Louisville, Kentucky.

McDonald, Donald, October, 1906.
With D. McDonald & Company, 991 Broadway, Albany, New York.

McDonald, William, October, 1906.
With D. McDonald & Company, 991 Broadway, Albany, New York.

McDowell, J. C., March, 1907.
General Manager, Kansas Natural Gas Company, Farmers' Bank Building, Pittsburgh, Pennsylvania.

McGowan, Henry Eddy, March, 1911.
General Manager, The Flatbush Gas Company, 273 Clarkson Street, Brooklyn, New York.

McGregor, William, October, 1906.
Manager, The Pawtucket Gas Company, 231 Main Street, Pawtucket, Rhode Island.

McGurty, William J., March, 1912.
Assistant Superintendent, Central Union Gas Company, 905 East 138th Street, New York, New York.

McIlhenny, James S., October, 1906.
Engineer, Washington Gas Light Company, 415 10th Street, N. W., Washington, District of Columbia.

McIlhenny, John, October, 1906.
Consulting Engineer, Washington (D. C.) Gas Light Company, 1339 Cherry Street, Philadelphia, Pennsylvania.

McIlhenny, John D., October, 1906.
Managing Director, Portsmouth (Va.) Gas Company, 1339 Cherry Street, Philadelphia, Pennsylvania.

McIntyre, Andrew, September, 1908.
Superintendent, Public Service Company of Northern Illinois, University and Maple Avenues, Evanston, Illinois.

McKay, William E., October, 1906.
Vice-President and General Manager, New England Gas & Coke Company, 111 Devonshire Street, Boston, Massachusetts.

McKee, G. W., October, 1906.
Vice-President and Manager, Eclipse Fuel Engineering Company, 707 South Main Street, Rockford, Illinois.

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McKenzie, W. H., October, 1906.
General Manager, Wyandotte County Gas Company, 6th Street and Minnesota Avenue, Kansas City, Kansas.

McLean, George, October, 1906.
President and Manager, The Key City Gas Company, 669 Main Street, Dubuque, Iowa.

McLean, H. B., March, 1908.
General Superintendent, Consolidated Gas Company, 130 East 15th Street, New York, New York.

McMillin, Emerson, October, 1906.
40 Wall Street, New York, New York.

McMillin, Marion, March, 1909.
Assistant Secretary, American Light & Traction Company, 40 Wall Street, New York, New York.

MacArthur, Donald, September, 1913.
Superintendent of Manufacture, Laclede Gas Light Company, Laclede Gas Building, St. Louis, Missouri.

Macbeth, A. B., October, 1906.
General Manager, Kansas Natural Gas Company, Independence, Kansas.

Macbeth, George T., October, 1906.
Engineer, Gas Department, Westchester Lighting Company, First Avenue and First Street, Mount Vernon, New York.

Macdonald, George, October, 1906.
President and General Manager, Nassau and Suffolk Lighting Company of Freeport, New York, 149 Broadway, New York, New York.

MacIntosh, Walter L., March, 1909.
Engineer, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

Mackie, G. W., September, 1913.
Assistant Superintendent, Milwaukee Coke & Gas Company, Colby-Abbott Building, Milwaukee, Wisconsin.

Macklin, A. Fred, September, 1911.
Assistant Superintendent, Consolidated Gas Company, 44th Street and North River, New York, New York.

MacSweeney, Joseph P., March, 1911.
Assistant Commercial Agent, Rochester Railway & Light Company, 34 Clinton Avenue, North, Rochester, New York.

Macy, Carlton, October, 1906.
President and General Manager, Queens Borough Gas & Electric Company, Far Rockaway, New York.

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MAINLAND, SINCLAIR, October, 1906.
Treasurer, Continental Public Utilities Company, Oshkosh, Wisconsin.

MAINLAND, WILLIAM, October, 1906.
President, Continental Public Utilities Company, Oshkosh, Wisconsin.

MALONE, M. E., October, 1906.
Manager Coke Department, Denver Gas & Electric Company, 900 15th Street, Denver, Colorado.

MALONEY, ANDREW P., September, 1907.
Official of Gas Companies, Lakewood (N. J.) Gas Company, Land Title Building, Philadelphia, Pennsylvania.

MALONEY, MARTIN 2D, March, 1913.
Assistant to Superintendent, City Gas Light Company, Post Office Apartments, Ocean City, New Jersey.

MANN, HOWARD E., October, 1906.
Engineer, Montreal Light, Heat & Power Company, Montreal, Canada.

MARKHUS, O. G. F., October, 1906.
Engineer, Idaho-Oregon Light & Power Company, Boise, Idaho.

MARKLEY, JOSEPH C., October, 1906.
Chief Engineer, Metropolitan Gas & Electric Company, 111 West Monroe Street, Chicago, Illinois.

MARKS, R. J., October, 1906.
Superintendent, City Gas Company, Norfolk, Virginia.

MARKS, WM. D., October, 1906.
Consulting Engineer, 623 Park Row Building, New York, New York.

MARPLE, WILLIAM MCKELVEY, October, 1906.
Chief Engineer, Scranton Gas & Water Company, 423 Jefferson Avenue, Scranton, Pennsylvania.

MARROW, GEORGE PEEK, September, 1910.
Assistant Engineer, with The Bartlett Hayward Company, Scott & McHenry Streets, Baltimore, Maryland.

MARSHALL, F. L., October, 1906.
Superintendent, Henrico County Gas Company, Barton Heights, Richmond, Virginia.

MARSHALL, WILLIAM H., October, 1906.
Assistant to Third Vice-President, The United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

MARTIN, EDMUND H., September, 1908.
Commercial Agent, Des Moines Gas Company, 412 West 7th Street, Des Moines, Iowa.

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MARTIN, EUGENE S., September, 1909.
Superintendent, Westchester Lighting Company, Mamaroneck Avenue, White Plains, New York.

MARTIN, JOHN, October, 1906.
President, Coast Counties Light & Power Company, 454 California Street, San Francisco, California.

MARTIN, JOHN GORDON, September, 1912.
Secretary and Manager, Gas & Electric Light Company, 7 North Indiana Street, Greencastle, Indiana.

MARTIN, WILLIAM PAUL, March, 1908.
Vice-President, Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

MASON, JOHN T., October, 1906.
Superintendent Third Ward Works, Milwaukee Gas Light Company, 129 25th Street, Milwaukee, Wisconsin.

MATHER, JOHN L., September, 1908.
General Manager, Counties Gas & Elecric Company, Ardmore, Pennsylvania.

MATHEWS, EUGENE HAMILTON, September, 1908.
Superintendent, Citizens' Works, Brooklyn Union Gas Company, 5th and Hoyt Streets, Brooklyn, New York.

MAXON, J. H., October, 1906.
President and General Manager, Central Indiana Gas Company, Muncie, Indiana.

MAYER, Jos. E. J., September, 1908.
Commercial Agent, Peoples Gas Light & Coke Company, Peoples Gas Building, Chicago, Illinois.

MAYERS, J. ALEX., October, 1906.
Gas Engineer; President Public Service Construction Company, 30 Broad Street, New York, New York.

MEAD, GILES W., September, 1908.
President, Indiana Natural Gas & Oil Company, The Linde Air Products Company, 42d Street Building, New York, New York.

MELICK, THOS L., September, 1907.
Engineer, Gas Department, Central Division, Public Service Gas Company, 249 East 4th Street, Plainfield, New Jersey.

MERCHANT, O. A., JR., March, 1907.
Manager, Bangor Gas Light Company, 18 Central Street, Bangor, Maine.

MERRIFIELD, L. L., October, 1906.
Consulting Gas Engineer, 269 Front Street, East, Toronto, Ontario, Canada.

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MERRITT, ALBERT H., October, 1906.
General Manager, Niagara Falls Gas & Electric Light Company, 306 Niagara Street, Niagara Falls, New York.

MERRITT, W. H., October, 1906.
General Manager, Fremont Gas, Electric Light & Power Company, Freemont, Nebraska.

MIDDLETON, ROBERT L., October, 1906.
1530 30th Street, N. W., Washington, District of Columbia.

MILLARD, FREDERICK CHAS., September, 1907.
Consulting Gas Engineer, 425 Merchants Trust Building, Los Angeles, California.

MILLER, ALTEN S., October, 1906.
Vice-President, Humphreys & Miller, Inc., 165 Broadway, New York, New York.

MILLER, CARROLL, October, 1906.
Engineer, Providence Gas Company, 20 Market Square, Providence, Rhode Island.

MILLER. C. O. G., October, 1906.
President, Pacific Lighting Company, 519 California Street, San Francisco, California.

MILLER, H. C., September, 1913.
Secretary and Treasurer, Northern Indiana Gas & Electric Company, Hammond, Indiana.

MILLER, IRA ABBOTT, October, 1906.
Assistant Secretary, Treasurer and Superintendent, Colorado Springs Light & Power Company, 30 Boulder Crescent, Colorado Springs, Colorado.

MILLER, ROBT. C., September, 1909.
Assistant Superintendent, Coke Department, Consolidated Gas Company of New York, 230 Avenue C, New York, New York.

MILLER, ROBERT S., October, 1906.
Manager, Jackson County Light, Heat & Power Company, 210 West Maple Avenue, Independence, Missouri.

MILLER, R. W., October, 1906.
Manager, Durham Light & Power Company, Durham, North Carolina.

MILLER, THOMAS DAVID, October, 1906.
Special Representative for E. M. Mancourt, Western Manager, The Consolidation Coal Company, 910 Fisher Building, Chicago, Illinois.

MILLER, V. A., September, 1907.
Superintendent and New Business Manager, Canandaigua Gas Light Company, 66 South Main Street, Canandaigua, New York.

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MILLER, WILLIAM A., October, 1906.
Engineer of Construction and Operation, National Chamber Oven Company, Cincinnati, Ohio.

MILNE, DAVID S., October, 1906.
Division Manager, Central Indiana Gas Company, Elwood, Indiana.

MILLS, SAMUEL ARCHIBALD, March, 1911.
Assistant Superintendent, Williamsburg Works, Brooklyn Union Gas Company, Foot of North 12th Street, Brooklyn, New York.

MILTON, MARSHALL M., September, 1912.
General Manager, Hagerstown Light & Heat Company, 10 North Jonathan Street, Hagerstown, Maryland.

MOCKETT, W. E., October, 1906.
Chief Engineer, Gas Deparment, Havana Electric Railway, Light & Power Company, Monte No. 1, Havana, Cuba.

MOORE, EDWIN A., March, 1908.
President, American Coke & Gas Construction Company, Camden, New Jersey; 2216 North 52d Street, Philadelphia, Pennsylvania.

MOORE, H. M., October, 1906.
Manager, Austin Gas Light Company, 907 Congress Avenue, Austin, Texas.

MOORHOUSE, LOUIS B., September, 1908.
Care of H. L. Doherty & Company, 60 Wall Street, New York, New York.

MOREHEAD, JOHN M., October, 1906.
Consulting Engineer, Peoples Gas Light & Coke Company, Peoples Gas Building, Chicago, Illinois.

MORGAN, JOHN EYRE, October, 1906.
408 Tioga Street, Johnstown, Pennsylvania.

MORRELL, EDWARD E., October, 1906.
Treasurer, National Gas & Water Company, 184 La Salle Street, Chicago, Illinois.

MORRIS, HENRY CHARLES, September, 1912.
General Manager, Dallas Gas Company, Dallas, Texas.

MORRIS, ROBERT C., JR., October, 1906.
Superintendent, New York & Richmond Gas Company, 694 Bay Street, Stapleton, Staten Island, New York.

MORRIS, W. CULLEN, October, 1906.
Engineer of Construction, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

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MORRIS, WILLIAM GILES, March, 1911.
Chief Clerk, Consolidated Gas Company, 124 East 15th Street, New York, New York.

MORRIS, WILLIAM T., October, 1906.
President and Treasurer, United States Gas & Electric Company, Penn Yan, New York.

MORRISON, HENRY K., October, 1906.
Manager, Brockton Gas Light Company, Brockton, Massachusetts.

MORTON, ALBERT B., September, 1907.
Superintendent, Rome Gas, Electric Light & Power Company, 139 North James Street, Rome, New York.

MORTON, F. N., October, 1906.
Engineer, with United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

MOSES, FRANK D., October, 1906.
Engineer, 7 North Stockton Street, Trenton, New Jersey.

MUELLER, M. E., September, 1909.
Assistant Superintendent of Manufacture, Astoria Light, Heat & Power Company, Astoria, Long Island, New York.

MULHOLLAND, S. E., October, 1906.
Assistant General Manager, Indiana Lighting Company, 1117 West Jefferson Street, Fort Wayne, Indiana.

MUNSON, RALPH IRA, March, 1912.
Secretary, Bridgeport Gas Light Company, 799 Main Street, Bridgeport, Connecticut.

MURDOCK, JAMES W., October, 1906.
General Superintendent, Underlying Companies, Associated Gas & Electric Company, Ithaca, New York.

MURDOCK, S. T., October, 1906.
Secretary and General Manager, Indiana Lighting Company, 4th and Ferry Streets, Lafayette, Indiana.

MURPHY, EDWARD J., September, 1913.
Assistant Chemist, Brooklyn Union Gas Company, 5th and Hoyt Streets, Brooklyn, New York.

MURRAY, JOHN J., March, 1911.
Superintendent, Allegheny Heating Company, 435 6th Avenue, Pittsburgh, Pennsylvania.

MYERS, EDWARD BRITTAIN, October, 1906.
Engineer, Northern Indiana Gas & Electric Company, 215 South Michigan Street, South Bend, Indiana.

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MYERS, JOSEPH B., October, 1906.
With The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

NAPHTALY, SAMUEL L., October, 1906.
Engineer, Operation and Maintenance, Pacific Gas & Electric Company, 445 Sutter Street, San Francisco, California.

NEELY, M. L., September, 1908.
Care of Fresno Gas Company, Fresno, California.

NELSON, JOHN F., March, 1909.
District Superintendent of Mains, Consolidated Gas Company of New York, 111th Street and 1st Avenue, New York, New York.

NETTLES, Rosco, September, 1911.
Secretary, Tampa Gas Company, Tampa, Florida.

NETTLETON, CHARLES H., October, 1906.
President, Derby Gas Company and New Haven Gas Light Company, 22 Elizabeth Street, Derby, Connecticut.

NEWBERRY, F. E., October, 1906.
Superintendent Gas Department, Green Bay Gas & Electric Company, Green Bay, Wisconsin.

NICHOLS, WILLIAM B., September, 1912.
Assistant General Manager, Citizens Gas Light Company, 11 Granite Street, Quincy, Massachusetts.

NICKERSON, FRANKLIN HEZEKIAH, March, 1911.
Chief Statistician, Consolidated Gas Company, 124 East 15th Street, New York, New York.

NORCROSS, J. ARNOLD, October, 1906.
Secretary and Treasurer, New Haven Gas Light Company, 80 Crown Street, New Haven, Connecticut.

NORRIS, ROLLIN, October, 1906.
General Superintendent, The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

NORTH, EDWIN, March, 1910.
Purchasing Agent, Consolidated Gas Company, 124 East 15th Street, New York, New York.

NORTON, WALTER F., October, 1906.
Superintendent, Gas Department, Nashua Light, Heat & Power Company, 70 East Pearl Street, Nashua, New Hampshire.

NORTON, WILLIAM J., Setember, 1913.
Special Consulting Work, Public Service Company of Northern Illinois, Middle West Utilities Company of Illinois, 112 West Adams Street, Chicago, Illinois.

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NUTE, JOSEPH E., October, 1906.
Manager, Fall River Gas Works Company, 155 North Main Street, Fall River, Massachusetts.

O'CONNELL, JOHN, March, 1913.
General Foreman of Gas Making, Consolidated Gas Company, 501 East 21st Street, New York, New York.

O'DONNELL, CHAS. J., April, 1908.
General Office, The United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

OFFUTT, M. WEBB, March, 1908.
Care of Electric Bond & Share Company, 71 Broadway, New York, New York.

OKAMOTO, SAKURA, March, 1909.
Chief Engineer and Manager, Nagoya Gas Company, Nagoya, Japan.

OLDS, HOWARD L., October, 1906.
Assistant Vice-President, Middle West Utilities Company, 112 West Adams Street, Chicago, Illinois.

OLMSTEAD, GEORGE G., October, 1906.
8 South Dearborn Street, Chicago, Illinois.

O'MALLEY, PATRICK, October, 1906.
Engineer, Western United Gas & Electric Company, 95 Prairie Street, Aurora, Illinois.

OSTHOFF, OTTO E., October, 1906.
Vice-President and Chief Engineer, H. M. Byllesby & Company, Insurance Exchange Building, Chicago, Illinois.

OTTEN, CHARLES, JR., March, 1907.
Superintendent, Haverhill Gas Light Company, 109 Merrimack Street, Haverhill, Massachusetts.

OWENS, H. THURSTON, September, 1907.
Vice-President and General Manager, La Crosse Gas & Electric Company, La Crosse, Wisconsin.

PAPST, HILMAR MAXIMILIAN, March, 1911.
General Manager, Portland Gas & Coke Company, 5th and Yamhill Streets, Portland, Oregon.

PAGE, CARTER H., JR., October, 1906.
Manager, Key West Gas Company, Key West, Florida.

PAIGE, CLIFFORD E., March, 1909.
Superintendent, Malden & Melrose Gas Light Company, Malden, Massachusetts.

PALMER, A. J., March, 1909.
Superintendent of Works, Bridgeport Gas Light Company, 799 Main Street, Bridgeport, Connecticut.

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PALMER, E. H., October, 1906.
President, Auburn Gas Company, Seneca Falls & Waterloo Gas Light Company, Geneva, New York.

PALMER, HARRY C., October, 1906.
Engineer, Buffalo Gas Company, 186 Main Street, Buffalo, New York.

PARCHER, SAMUEL L., September, 1912.
Superintendent of Gas Department, York Light & Heat Company, 233 Main Street, Biddeford, Maine.

PARKER, FRANK H., October, 1906.
Manager, Burlington Light & Power Company, 102 South Winooski Avenue, Burlington, Vermont.

PARKER, JOSEPH SMITH, October, 1906.
Superintendent, Frankford District, United Gas Improvement Company, 4427 Frankford Avenue, Philadelphia, Pennsylvania.

PARKER, RICHARD MARSH, October, 1906.
General Manager, Fort Dodge Gas & Electric Company, 24 South 9th Street, Fort Dodge, Iowa.

PARSHALL, A., March, 1913.
Consulting Engineer, Appraising Properties of Gas and Electric Companies, Rochester Railway & Light Company, 34 Clinton Avenue, North, Rochester, New York.

PARTRIDGE, WARREN, September, 1909.
Penn Public Service Company, Clearfield, Pennsylvania.

PATTEN, J. A., October, 1906.
Manager, Gas Company, Winona, Wisconsin.

PAYNE, A. I., October, 1906.
Consulting Gas Engineer, 7 Belmont Block, Calgary, Alberta, Canada.

PEARSON, J. A., October, 1906.
Purchasing Agent, The United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

PEARSON, W. H., October, 1906.
34 Sherbourne Street, Toronto, Ontario, Canada.

PEARSON, W. H., JR., October, 1906.
Engineer, Pearson Carbon Remover Company, 809 Woodward Avenue, Detroit, Michigan.

PECK, HENRY W., March, 1912.
Vice-President and General Manager, Mohawk Gas Company, 511 State Street, Schenectady, New York.

PELTON, BERT F., October, 1906.
Superintendent Gas Distribution, St. Paul Gas Light Company, 6th and Jackson Streets, St. Paul, Minnesota.

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PENINGTON, DUDLEY W., March, 1912.
Assistant Superintendent, South Division, Street Department, Peoples Gas Light & Coke Company, 38 West 64th Street, Chicago, Illinois.

PERKINS, BENJAMIN W., October, 1906.
General Manager, Hartford City Gas Light Company, 565 Main Street, Hartford, Connecticut.

PERKINS, JAY HUGH, October, 1906.
Consulting Electrical Engineer, Susquehanna Railway & Light Company, 40 Wall Street, New York, New York.

PERRY, JOSEPH A., October, 1906.
Assistant to General Superintendent, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

PETERS, HENRY, March, 1910.
Superintendent, North Station, Peoples Gas Light & Coke Company, 1122 Crosby Street, Chicago, Illinois.

PETTES, W. H., October, 1906.
General Auditor, Public Service Gas Company, Post Office Box 590, Newark, New Jersey.

PETURA, FRANK JOSEPH, October, 1906.
Gas Engineer, care of H. L. Doherty & Company, 60 Wall Street, New York, New York.

PHELPS, NELSON GORDON, September, 1913.
Industrial Engineer, Citizens Gas & Electric Company, 308 East Fourth Street, Waterloo, Iowa.

PHIFER, WALTER JAMES, March, 1908.
With United Gas Improvement Company, Vicksburg, Mississippi.

PHILBRICK, JOSEPH E., September, 1911.
General Manager, York Gas Company, 127 West Market Street, York, Pennsylvania.

PIPKIN, JESSE E., September, 1913.
Superintendent, Station B, Laclede Gas Light Company, Laclede Gas Building, St. Louis, Missouri.

PLUMMER, H. W., October, 1906.
Manager, Asheville Power & Light Company, Asheville, North Carolina.

POLK, ROGER W., Ocober, 1906.
Engineer, Laclede-Christy Clay Products Company, Manchester and Sulphur Avenues, St. Louis, Missouri.

POLLITT, L. IRVING, October, 1906.
Vice-President and General Manager, Southern Gas & Electric Corporation, 213 Courtland Street, Baltimore, Maryland.

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PORTER, EDWARD, September, 1913.
Special Accountant, General Auditor's Department, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

PORTER, JOSEPH F., October, 1906.
President, Tri-City Railway & Light Company, Davenport, Iowa.

POWELL, DAVID A., September, 1909.
Engineer's Assistant, Milwaukee Gas Light Company, 182 Wisconsin Street, Milwaukee, Wisconsin.

POWELL, WILLIAM R., October, 1906.
Superintendent, Columbus Gas & Fuel Company, 135 North Front Street, Columbus, Ohio.

PRATT, EDWARD G., October, 1906.
Consulting Gas Engineer and President, Boone (Iowa) Gas Company, 627 Peoples Gas Building, Chicago, Illinois.

PRICHARD, CHARLES F., October, 1906.
Vice-President and General Manager, Lynn Gas & Electric Company, 90 Exchange Street, Lynn, Massachusetts.

PRICHARD, CHAS. R., September, 1909.
Superintendent, Beverly Gas & Electric Company, Beverly, Massachusetts.

PRIEST, GEORGE HEYWOOD, March, 1910.
Gas Engineer, Stone & Webster Engineering Corporation, 147 Milk Street, Boston, Massachusetts; R. F. D., Framingham, Massachusetts.

PRINTZ, CHARLES H., October, 1906.
General Sales Agent, The Stacey Manufacturing Company, Post Office Station P, Cincinnati, Ohio.

PURCELL, THEO. V., October, 1906.
122 South Michigan Avenue, Chicago, Illinois.

PUTNAM, WILLIAM R., October, 1906.
Manager, with Utah Power & Light Company, Salt Lake City, Utah.

QUACKENBUSH, CHARLES H., October, 1906.
Manager, St. Clair County Gas & Electric Company, 414 Missouri Avenue, East St. Louis, Illinois.

QUINN, A. K., October, 1906.
President and General Manager, Newport Gas Light Company, 181 Thames Street, Newport, Rhode Island.

RAABE, CHARLES, March, 1910.
Assistant to Superintendent, Consolidated Gas Company, 501 East 21st Street, New York, New York.

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RAFFERTY, JAMES ALOYSIUS, September, 1910.
Assistant Superintendent, Peoples Gas Light & Coke Company, 1122 Crosby Street, Chicago, Illinois.

RAMSBURG, CHARLES J., October, 1906.
Second Vice-President, H. Koppers Company, 5 South Wabash Avenue, Chicago, Illinois.

RAMSAY, DAVID G., September, 1908.
Superintendent, 22d Street Station, Peoples Gas Light & Coke Company, 236 West 63d Street, Chicago, Illinois.

RAMSDELL, GEORGE G., October, 1906.
Secretary and Treasurer, American Gas Institute, 29 West 39th Street, New York, New York.

RANDOLPH, WILLIAM W., October, 1906.
Consulting Engineer, Woolworth Building, 233 Broadway, New York, New York.

RAY, WILLIAM DANIEL, March, 1911.
Manager, Northern Indiana Gas & Electric Company, 571 Hohman Street, Hammond, Indiana.

REED, JAMES H., JR., September, 1909.
General Purchasing Agent, Philadelphia Company, 435 Sixth Avenue, Pittsburgh, Pennsylvania.

REED, JOSEPH A., March, 1911.
Assistant General Superintendent, Philadelphia Company, 435 Sixth Avenue, Pittsburgh, Pennsylvania.

REES, RICHARD, October, 1906.
Superintendent Bookkeeping Department, Peoples Gas Light & Coke Company, Michigan Avenue and Adams Street, Chicago, Illinois.

REIMERS, FREDERICK WILLIAM, September, 1912.
General Superintendent, Peoples Power Company, 914 Second Avenue, Rock Island, Illinois.

REINACH, HUGO B., March, 1911.
Assistant General Superintendent, Commercial Department, Consolidated Gas Company, 124 East 15th Street, New York, New York.

REINHARD, SOLON A., September, 1910.
Assistant Superintendent of Works, Peoples Gas Light & Coke Company, 4634 Drexel Avenue, Chicago, Illinois.

REINICKER, CHARLES E., March, 1912.
Engineering and Street Departments, Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

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REITEMEYER, A. F., October, 1906.
Superintendent, Secretary and Treasurer, Perth Amboy Gas Light Company, 154 Smith Street, Perth Amboy, New Jersey.

REW, IRWIN, October, 1906.
Vice-President, DeKalb County (Ill.) Gas Company, and Sterling (Ill.) Gas & Electric Company, 108 South LaSalle Street, Chicago, Illinois.

RHOADES, WILLIAM R., October, 1906.
General Manager, Northern Central Gas Company, Williamsport, Pennsylvania.

RICE, HENRY L., October, 1906.
General Manager, Western United Gas & Electric Company, Aurora, Illinois.

RICHARDS, J. L., September, 1907.
President and General Manager, Boston Consolidated Gas Company, 24 West Street, Boston, Massachusetts.

RICHARDS, W. A., October, 1906.
Mechanical and Gas Engineer, 216 North Carroll Street, Madison Wisconsin.

RICHARDSON, WALTER W., October, 1906.
President, Iroquois Natural Gas Company, 205 Iroquois Building, Buffalo, New York.

RICHTER, ARTHUR W., October, 1906.
Professor of Engineering, University of Montana, Bozeman, Montana.

RIEHA, EDWARD L., October, 1906.
Secretary, Sumter Gas & Power Company, Sumter, South Carolina; 213 Courtland Street, Baltimore, Maryland.

RISELAY, WILLIAM S., October, 1906.
Secretary and Treasurer, Buffalo Gas Company and Peoples Gas Light & Coke Company, 186 Main Street, Buffalo, New York.

RITTER, CHARLES S., October, 1906.
Secretary and Assistant Treasurer, Detroit City Gas Company, Gas Office Building, Detroit, Michigan.

ROBERTS, E. C., September, 1907.
Division Agent, Public Service Gas Company, 114 Main Street, Hackensack, New Jersey.

ROBERTS, F. M., October, 1906.
Manager, Haverhill Gas Light Company, 109 Merrimack Street, Haverhill, Massachusetts.

ROBERTS, GEORGE J., October, 1906.
First Vice-President, Public Service Gas Company, 759 Broad Street, Newark, New Jersey.

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ROBERTS, GEO. W., March, 1909.
Treasurer, Bridgeport Gas Company, 799 Main Street, Bridgeport, Connecticut.

ROBISON, CHARLES D., October, 1906.
Consulting Engineer, Forstall & Robison, 84 William Street, New York, New York.

ROCHAT, HENRY, October, 1906.
Superintendent of Manufacture, Indianapolis Gas Company, Majestic Building, Indianapolis, Indiana.

RODGERS, WILLIAM JOSEPH, Sepember, 1913.
Assistant Superintendent of Distribution, Public Service Gas Company, 2d and Cherry Streets, Camden, New Jersey.

ROESER, CHARLES J., September, 1907.
Engineer, Bergen Division, Public Service Gas Company, 118 Main Street, Hackensack, New Jersey.

ROGERS, FRED ALFRED, September, 1913.
Secretary and General Manager, Watertown Light & Power Company, 137 Arsenal Sreet, Watertown, New York.

ROGERS, JOHN MCCLELLAND, September, 1908.
Assistant to Purchasing Agent, Public Service Gas Company, 759 Broad Street, Newark, New Jersey.

ROGERS, W. H., October, 1906.
Agent, Passaic Division, Public Service Gas Company, 188 Ellison Street, Paterson, New Jersey.

ROOHAN, PATRICK F., October, 1906.
Manager, Adirondack Electric Power Corporation, 491 Broadway, Saratoga Springs, New York.

ROPER, GEORGE D., October, 1906.
Vice-President, Boone (Iowa) Gas Company, Rockford, Illinois.

ROSENQUEST, EUGENE H., October, 1906.
President and General Manager, Bronx Gas & Electric Company, Walker and Frisbie Avenues, Westchester, New York.

ROSENTHAL, ALBERT, October, 1906.
Engineer, Claiborne, Johnston & Company, 901 Calvert Building, Baltimore, Maryland.

ROSS, J. CHARLES, October, 1906.
Care of Thomas West & Company, Perth Amboy, New Jersey.

ROSSMAN, G. M., October, 1906.
Treasurer, Keene Gas & Electric Company, 18 Roxbury Street, Keene, New Hampshire.

ROWLAND, CHARLES L., October, 1906.
Consulting Engineer, American Welding Company, Carbondale, Pennsylvania.

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ROWLAND, WILLIAM L., October, 1906.
Chemical Engineer, Henry Bower Chemical Manufacturing Company, 2815 Gray's Ferry Road, Philadelphia, Pennsylvania.

ROYCE, FREDERICK P., October, 1906.
Stone & Webster Management Association, 147 Milk Street, Boston, Massachusetts.

RUEGENBERG, JOHN M., March, 1907.
Superintendent, Northern Liberties Gas Company, United Gas Improvement Company, 3d and Brown Streets, Philadelphia, Pennsylvania.

RUNNER, R. K., October, 1906.
Secretary, Gas Company, Charles City, Iowa.

RUSBY, JOHN M., October, 1906.
Engineer of Tests, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

RUSSELL, DANIEL R., October, 1906.
President, Parker-Russell Mining & Manufacturing Company, Laclede Gas Building, St. Louis, Missouri.

RUSSELL, HERMAN, September, 1907.
Superintendent of Gas Manufacturing, Rochester Railway & Light Company, 634 Averill Avenue, Rochester, New York.

RUTLEDGE, FRED J., September, 1909.
Commercial Agent, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

SANDS, HOWARD T., March, 1913.
General Manager, Malden & Melrose Gas Light Company, 201 Devonshire Street, Boston, Massachusetts.

SANFORD, GEORGE RUGGLES, March, 1913.
Superinendent, Semet-Solvay Company, Geneva, New York.

SARGEANT, FRANK WASHBURN, September, 1908.
Superintendent of Distribution, Citizens Gas Company, 31 South Pennsylvania Street, Indianapolis, Indiana.

SARGENT, FRED H., October, 1906.
Assistant Agent, Lawrence Gas Company, 370 Essex Street, Lawrence, Massachusetts.

SAWYER, F. H., October, 1906.
General Manager, New Bern Gas Company, New Bern, North Carolina.

SCHADDELEE, RICHARD, October, 1906.
Vice-President, United Light & Railway Company, 411 Michigan Trust Building, Grand Rapids, Michigan.

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SCHAUER, FRANK F., October, 1906.
Assistant Engineer, Kansas City Gas Company, 910 Grand Avenue, Kansas City, Missouri.

SCHENCK, RUDOLPH, October, 1906.
Assistant Engineer, Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

SCHERCK, LEON H., October, 1906.
Sales Manager, Central Hudson Gas & Electric Company, 50 Market Street, Poughkeepsie, New York.

SCHICK, KARL AUGUST, March, 1911.
Assistant Superintendent, Commercial Department, Rochester Railway & Light Company, 34 Clinton Avenue, North, Rochester, New York.

SCHILLER, CHARLES C., October, 1906.
Superintendent of Meters, Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

SCHINDLER, MORRIS DANIEL, September, 1912.
Manager, Gas Light Company of Augusta, Augusta, Georgia.

SCHMIDT, EMIL G., October, 1906.
President, Des Moines City Railway Company, Des Moines, Iowa.

SCHMIDT, F. W., October, 1906.
Division Agent, Public Service Gas Company, 84 Sip Avenue, Jersey City, New Jersey.

SCHNEIDER, PHILIP J., March, 1911.
Treasurer, Central Union Gas Company, 519 Courtlandt Avenue, New York, New York.

SCHOBEL, FREDERICK A., March, 1911.
Superintendent of Distribution, Municipal Gas Company, 1131 Broadway, Albany, New York.

SCHROEDER, ALBERT GEORGE, September, 1912.
Purchasing Agent, Grand Rapids Gas Light Company, 110 Grand Avenue, Grand Rapids, Michigan.

SCHUTT, HARRY S., October, 1906.
General Manager, C. H. Geist Company, 1127 Land Title Building, Philadelphia, Pennsylvania.

SCHWABE, WALTER P., March, 1911.
General Manager, Gas & Electric Company, Windsor Locks, Connecticut.

SCHWARM, C. A., October, 1906.
General Superintendent, Henry M. Wallace Company, 705 Union Trust Building, Detroit, Michigan.

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Scobell, E. C., October, 1906.
Assistant Auditor, Rochester Railway & Light Company, 34 Clinton Avenue, North, Rochester, New York.

Scofield, Thomas, September, 1910.
Illuminating Engineer, Consolidated Gas Company, 124 East 15th Street, New York, New York.

Scott, Alexander H., September, 1908.
Engineer, Peoples Gas Light Company, 39 Hanover Street, Manchester, New Hampshire.

Scott, John Joseph, September, 1912.
Superintendent, Lewiston Gas Light Company, 88 Shawmut Street, Lewiston, Maine.

Scott, John M., September, 1908.
Secretary and Treasurer, Kansas City Gas Company, 910 Grand Avenue, Kansas City, Missouri.

Scott, Rossiter Stockton, March, 1908.
Assistant Engineer, Consolidated Gas, Electric Light & Power Company, Baltimore, Maryland.

Scranton, George H., October, 1906.
Secretary, Derby Gas Company, 22 Elizabeth Street, Derby, Connecticut.

Scranton, Worthington, October, 1906.
Vice-President, Hyde Park Gas Company, 115 Wyoming Avenue, Scranton, Pennsylvania.

Seamon, J. Fred, October, 1906.
Constructing Engineer, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

Searle, Robert M., October, 1906.
Vice-President, Rochester Railway & Light Company, 34 Clinton Avenue, North, Rochester, New York.

Secord, Warren L., October, 1906.
General Superintendent of Meters, Westchester Lighting Company, First Avenue and First Street, Mt. Vernon, New York.

Seddon, Samuel Venable, September, 1913.
Superintendent, Metropolitan Works, Brooklyn Union Gas Company, 12th Street and 2d Avenue, Brooklyn, New York.

Serrill, William J., October, 1906.
Engineer of Distribution, Philadelphia Gas Works, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

Seymour, Fredk. Warner, September, 1912.
Superintendent of Manufacture, Grand Rapids Gas Light Company, Grand Rapids, Michigan.

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SEYMOUR, WILLIAM W., October, 1906.
President, Gray's Harbor Gas Company of Aberdeen, Washington, 324 Tacoma Building, Tacoma, Washington.

SHACKLETTE, R., October, 1906.
Secretary and General Manager, Big Rapids Gas Company, Big Rapids, Michigan.

SHAEFER, JOHN WALLACE, March, 1911.
Superintendent, The Milwaukee Coke & Gas Company, 187 Greenfield Avenue, Milwaukee, Wisconsin.

SHAFFNER, SAMUEL C., March, 1907.
Middle West Utilities Company, 112 West Adams Street, Chicago, Illinois.

SHATTUCK, A. F., October, 1906.
Chief Chemist, The Solvay Process Company, Jefferson Avenue, West, Detroit, Michigan.

SHATTUCK, JOHN D., October, 1906.
General Manager, Philadelphia Gas & Electric Company, 6th and Welsh Streets, Chester, Pennsylvania.

SHAW, H. S., October, 1906.
Treasurer and Superintendent, Webster Electric Company, Webster, Massachusetts.

SHAW, JOHN CARGILL, September, 1913.
Engineer's Assistant, Astoria Light, Heat & Power Company, Astoria, Long Island, New York.

SHEPARD, DAVID JAMES, March, 1911.
Engineer, 205 Hooper Street, Brooklyn, New York.

SHEPARD, FREDERICK C., October, 1906.
Superintendent, Minneapolis Gas Light Company, 16 Seventh Street, Minneapolis, Minnesota.

SHEPARD, RICHARD, September, 1912.
Superintendent of Pavements and General Storekeeper, Consolidated Gas Company, 124 East 15th Street, New York, New York.

SHERWOOD, E. J., October, 1906.
Manager, Mitchell Power Company, Mitchell, South Dakota.

SHERWOOD, M. S., September, 1907.
Agent, Gas Department, Public Service Gas Company, 112 Mountain Avenue, Summit, New Jersey.

SHIEBLER, MARVIN, September, 1908.
Gas Engineer, 30 Church Street, New York, New York.

SHIELDS, HENRY C., March, 1913.
Vice-President and General Manager, Troy Gas Company, Troy, New York.

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SILVERTHORN, JAMES C., March, 1911.
Gas and Electric Light Company, Evansville, Indiana.

SIMONS, KEATING LEWIS, September, 1907.
Vice-President and General Manager, El Paso Gas and Electric Company, El Paso, Texas.

SIMPSON, COLIN C., March, 1911.
Assistant General Superintendent of Mains and Services, Consolidated Gas Company, 124 East 15th Street, New York, New York.

SIMPSON, HENRY, March, 1911.
Superintendent, Consolidated Gas Company, 112 West 42d Street, New York, New York.

SINGER, SIDNEY CHARLES, March, 1908.
Superintendent of Distribution, Syracuse Lighting Company, 143 Mechanic Street, Syracuse, New York.

SINSEL, OTIS A., October, 1906.
Assistant Engineer, Detroit City Gas Company, 57 Webb Avenue, Detroit, Michigan.

SLADE, RICHMOND E., October, 1906.
Manager Gas Department, New Orleans Railway & Light Company, 201 Baronne Street, New Orleans, Louisiana.

SLOAN, J. C., October, 1906.
Manager, Port Huron Gas Company, Port Huron, Michigan.

SMART, F. R., JR., October, 1906.
132 Jamaica Avenue, Flushing, Long Island, New York.

SMITH, A. J., October, 1906.
Superintendent, Concord Light & Power Company, 90 North Main Street, Concord, New Hampshire.

SMITH, ELMER W., March, 1907.
Manager, Kewanee Light & Power Company, Kewanee, Illinois.

SMITH, GEO. P., JR., September, 1910.
Superintendent of Distribution, Old Colony Gas Company, Quincy Avenue, East Braintree, Massachusetts.

SMITH, J. HENDERSON, September, 1913.
Chief Clerk, General Auditor's Department, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

SMITH, LOUIS C., September, 1913.
Manager, Fulton County Gas & Electric Company, 18 East Fulton Street, Gloversville, New York.

SMITH, RAYMOND H., March, 1909.
General Manager, Jackson Light & Traction Company, 720 Arlington Street, Jackson, Mississippi.

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SNOW, WILLIAM H., October, 1906.
General Manager, New Bedford Gas & Edison Light Company, 125 Middle Street, New Bedford, Massachusetts.

SNYDER, ALBERT I., September, 1911.
Engineer, 567 Paris Avenue, Grand Rapids, Michigan.

SNYDER, CHARLES S., March, 1907.
Superintendent, West Philadelphia District, United Gas Improvement Company, 4650 Market Street, Philadelphia, Pennsylvania.

SNYDER, HARRY L., March, 1911.
Secretary and Treasurer, New York & Queens Electric Light & Power Company, 444 Jackson Avenue, Long Island City, New York.

SOMBART, W. E., October, 1906.
Secretary and Treasurer, Sombart Gas Company, Boonville, Missouri.

SOULT, GEORGE H., March, 1911.
Assistant District Superintendent, Public Service Gas Company, 175 Ridgewood Avenue, Ridgewood, New Jersey.

SPANGENBERG, BREWSTER H., October, 1906.
Toms River, New Jersey.

SPEAKER, GEORGE S., March, 1912.
Treasurer and General Manager, Lebanon Gas & Fuel Company, 17 North 8th Street, Lebanon, Pennsylvania.

SPEAR, M. H., October, 1906.
Secretary and Manager, New York & Queens Gas Company, 88 Main Street, Flushing, New York.

SPENCER, ELLIOTT L., March, 1912.
Engineer, Central Union Gas Company, 905 East 138th Street, New York, New York.

SPERLING, NATH. JOS., September, 1909.
Assistant Superintendent, Mechanical Department, Astoria Light, Heat & Power Company, Astoria, Long Island, New York.

SPITZGLASS, JACOB M., September, 1912.
Mechanical Engineer, Peoples Gas Light & Coke Company, 1701 Peoples Gas Building, Chicago, Illinois.

SPRAGLE, L. D., October, 1906.
General Manager, Berwick Gas Company, 104 Mulberry Street, Berwick, Pennsylvania.

SQUIER, HAROLD NEWTON, September, 1912.
Superintendent, Hyde Park Gas Company, 115 Wyoming Avenue, Scranton, Pennsylvania.

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STACEY, FREDERICK A., October, 1906.
President, Chillicothe Gas & Water Company, Chillicothe, Ohio.

STACK, EDWARD M., March, 1910.
General Superintendent, Hyde Park Gas Company, Scranton, Pennsylvania.

STANIFORD, ARTHUR FOWLER, March, 1908.
Vice-President, Brooklyn Union Gas Company, 180 Remsen Street, Brooklyn, New York.

STANNARD, CLARE N., October, 1906.
Secretary and Commercial Manager, Denver Gas & Electric Company, 900 15th Street, Denver, Colorado.

STARK, ARTHUR WILLIAM, March, 1913.
Engineer's Assistant, Consolidated Gas Company of New York. 124 East 15th Street, New York, New York.

STEALEY, LEE G., March, 1912.
Manager, St. Charles Lighting Company, St. Charles, Missouri.

STEELE, G. W., March, 1909.
Manager, Lehigh-Northampton Light, Heat & Power Company, 123 Bridge Street, Catasauqua, Pennsylvania.

STEINWEDELL, CARL, October, 1906.
515 North 8th Street, Quincy, Illinois.

STEINWEDELL, GEORGE, October, 1906.
Commercial Manager, St. Paul Gas Light Company, Sixth and Jackson Streets, St. Paul, Minnesota.

STEINWEDELL, W. E., October, 1906.
Secretary, Gas Machinery Company, 1900 Euclid Avenue, Cleveland, Ohio.

STEVICK, CRIST H., October, 1906.
Assistant Superintendent, Ravenswood Works, New Amsterdam Gas Company, 237 Grand Avenue, Astoria, Long Island, New York.

STEWART, SAMUEL B., October, 1906.
General Contracting Agent, Philadelphia Company, and Consolidated Gas Company, 435 Sixth Avenue, Pittsburgh, Pennsylvania.

STILES, GEORGE WARREN, September, 1912.
Superintendent, Fitchburg Gas & Electric Light Company, Fitchburg, Massachusetts.

STILES, HARRY B., October, 1906.
Purchasing Agent, St. Paul Gas Light Company, Sixth and Jackson Streets, St. Paul, Minnesota.

STILES, LINFORD SPEARING, March, 1910.
Construction Engineer, Brooklyn Union Gas Company, 556 Kent Avenue, Brooklyn, New York.

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STILLSON, HOWARD G., October, 1906.
Superintendent, Boone Gas Company, Boone, Iowa.

STILWELL, JOHN, September, 1909.
Efficiency Engineer, Consolidated Gas Company, 124 East 15th Street, New York, New York.

STIRZEL, JACOB W., October, 1906.
Superintendent of Holder Stations and Pumping Mains, Philadelphia Gas Works, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

ST. JOHN, JOHN, September, 1909.
Secretary and Treasurer, Madison Gas & Electric Company, 120 East Main Street, Madison, Wisconsin.

STONE, C. H., March, 1911.
Manager, Gas Department, Orange County Lighting Company, 12 South Street, Middletown, New York.

STONE, FREDERICK W., October, 1906.
Manager, The Ashtabula Gas Company, Ashtabula, Ohio.

STRAIN, G. A., October, 1906.
Superintendent, Gas Department, Helena Railway & Light Company, Helena, Montana.

STRANGE, HARRY LATIMER, March, 1911.
Manager, Honolulu Gas Company, Ltd., Honolulu, Hawaii.

STRECKER, ALEXANDER H., October, 1906.
Consulting Engineer, Public Service Gas Company, 235 Mt. Pleasant Avenue, Newark, New Jersey.

STROBRIDGE, WM., March, 1909.
Engineer, United States Cast Iron Pipe & Foundry Company, Burlington, New Jersey.

STROHN, C. B., October, 1906.
District Manager, Western United Gas & Electric Company, Elgin, Illinois.

STROHN, R. N., October, 1906.
Vice-President and Treasurer, Western United Gas & Electric Company, Aurora, Illinois.

STROUD, MORRIS W., October, 1906.
President, The American Gas Company, West Washington Square, Philadelphia, Pennsylvania.

STULL, C. RODMAN, March, 1909.
Resident Manager, Waukesha-American Gas Co., Waukesha, Wisconsin.

SUCHOMEL, THOMAS, October, 1906.
Superintendent of Gas Works, Cedar Rapids Gas Light Company, 501 6th Avenue, Cedar Rapids, Iowa.

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SULLIVAN, BEVERLY NATHANIEL, March, 1908.
Manager, Winston-Salem Light & Fuel Company, Winston-Salem, North Carolina.

SUMMERS, GEORGE, October, 1906.
Chief Engineer, Citizens Gas Company, 645 East 21st Street, Indianapolis, Indiana.

SUMNER, ARTHUR WILLIAM, March, 1913.
Gas Engineer and Manager, Grays & Tilbury Gas Company, Bank Building, Grays, Essex, England.

SWAN, GEO. J., September, 1907.
Superintendent, Consumers Light, Heat & Power Company, 214 East First Street, Topeka, Kansas.

SWANN, HARRY R., October, 1906.
Chief Inspector (*ex-Officio*), Louisville Gas Company, 654 South Floyd Street, Louisville, Kentucky.

SWEETMAN, M. M., October, 1906.
General Superintendent, Kansas Natural Gas Company, 3410 Baltimore Avenue, Kansas City, Missouri.

SWEETMAN, W. D., October, 1906.
Superintendent, Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

TAIT, FRANK M., October, 1906.
President, The Dayton Power & Light Company, 124 East Fourth Street, Dayton, Ohio.

TALBOTT, FRANK, October, 1906.
Superintendent and Treasurer, City of Danville Water & Light Department, Main Street, Danville, Virginia.

TAUSSIG, J. HAWLEY, October, 1906.
Engineer of Design, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

TAYLOR, ALLYN CHANDLER, September, 1908.
Engineering Assistant, Allentown Gas Company, 516 Hamilton Street, Allentown, Pennsylvania.

TAYLOR, JOHN BYRON, September, 1907.
Treasurer, Watertown Gas Light Company, Watertown, New York.

TAYLOR, WM. H., September, 1908.
Manager, Omaha Gas Company, 1509 Howard Street, Omaha, Nebraska.

TENNEY, ALBERT BALL, September, 1907.
Vice-President, Malden Electric Company, Malden & Melrose Gas Light Company, 201 Devonshire Street, Boston, Massachusetts.

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TENNEY, CHARLES H., October, 1906.
President, Springfield Gas Company, Springfield, Massachusetts.

TERRY, H. WARREN, JR., October, 1906.
Superintendent, Northern Westchester Lighting Company, 127 Main Street, Ossining, New York.

THOMAS, CARL C., March, 1912.
Professor of Mechanical Engineering, Johns Hopkins University, 114 Roland Avenue, Baltimore, Maryland.

THOMAS, CHARLES G. M., October, 1906.
Vice-President and General Manager, New York & Queens Electric Light & Power Company, 244 Jackson Avenue, Long Island City, New York.

THOMAS, NATHANIEL W., September, 1912.
Chief Inspector, Bureau of Gas, 1513 Centennial Avenue, Philadelphia, Pennsylvania.

THOMAS, W. F., September, 1907.
Agent, Gas and Electric Departments, Public Service Gas Company, 80 Albany Street, New Brunswick, New Jersey.

THOMPSON, CLARENCE E., September, 1912.
President, Wallingford Gas Light Company, 810 Chapel Street, New Haven, Connecticut.

THOMPSON, PAUL, October, 1906.
Fifth Vice-President, The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

THOMSON, GEORGE W., October, 1906.
Manager, New Business Department, Philadelphia Suburban Gas & Electric Company, 6th and Welsh Streets, Chester, Pennsylvania.

THOMSON, W. H., JR., September, 1908.
Chief Operating Engineer, Des Moines Electric Company, Des Moines, Iowa.

THORN, FREDK. GODFREY, JR., October, 1906.
Engineer of Construction, Philadelphia Gas Works, 1401 Arch Street, Philadelphia, Pennsylvania.

THUMAN, FREDERIC, September, 1907.
Chief Engineer and General Manager, Humphreys & Glasgow, 38 Victoria Street, London, S. W., England.

THWING, ORRELL O., October, 1906.
Chief Engineer, Western Gas Construction Company, 3002 Thompson Avenue, Fort Wayne, Indiana.

TINCHER, T. SYMMES, September, 1911.
Superintendent of Manufacture, Washington Gas Light Company, 3918 New Hampshire Avenue, N. W., Washington, District of Columbia.

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TIPPY, B. O., October, 1906.
Consulting Engineer, 710 Union Trust Building, Detroit, Michigan.

TIPPY, CHARLES W., October, 1906.
Care of Hodenpyl, Hardy & Company, 2004 Dime Bank Building, Detroit, Michigan.

TITZEL, R. JOHN, September, 1911.
Gas Engineer, United Gas & Electric Corporation, 40 Wall Street, New York, New York.

TOBEY, FRANKLIN, JR., October, 1906.
Manager, Kingston Gas & Electric Company, 611 Broadway, Kingston, New York.

TOLMAN, WILLIAM N., October, 1906.
Constructing Engineer, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

TOMPKINS, JOHN P., October, 1906.
Secretary and Treasurer, Heat, Light & Power Company, Pleasantville, New Jersey.

TOWNSEND, ALFRED FREEMAN, September, 1913.
Manager, Blackstone Valley Gas & Electric Company, 3 Clinton Street, Woonsocket, Rhode Island.

TRAVER, A. F., October, 1906.
Superintendent, Gas Department, Gas & Electric Company, 900 15th Street, Denver, Colorado.

TRAVIS, FRANK M., October, 1906.
Secretary, Winsted Gas Company; Treasurer, Torrington Electric Light & Gas Company, 58 Church Street, Torrington, Connecticut.

TRELEAVEN, L. G., September, 1907.
Secretary and Manager, Consumers Light, Heat & Power Company, 824 Kansas Avenue, Topeka, Kansas.

TRIPP, GEORGE B., September, 1910.
Vice-President and General Manager, Harrisburg Light & Power Company, Harrisburg, Pennsylvania.

TUCKER, C. A., October, 1906.
Assistant Treasurer, Rochester Railway & Light Company, 34 Clinton Avenue, North, Rochester, New York.

TULL, LUCIEN, P. F., October, 1906.
Auditor, New Amsterdam Gas Company, 22 East 22d Street, New York, New York.

TURNER, ALFRED E., September, 1912.
Assistant General Superintendent of Meters, Consolidated Gas Company, 124 East 15th Street, New York, New York.

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TURNEY, HENRY D., October, 1906.
President, The Columbus Gas & Fuel Company, 135 North Front Street, Columbus, Ohio.

TUTTLE, W. B., October, 1906.
Vice-President and General Manager, San Antonio Gas & Electric Company, 305 East Houston Street, San Antonio, Texas.

TUTWILER, CARRINGTON CABELL, October, 1906.
Consulting Chemist, 1630 Real Estate Trust Building, Philadelphia, Pennsylvania.

UHLIG, EDWARD C., March, 1911.
Chief Chemist, Brooklyn Union Gas Company, 5th and Hoyt Streets, Brooklyn, New York.

UNDERHILL, HENRY L., September, 1908.
Assistant Engineer of Manufacture, Consolidated Gas Company of New York, Astoria, Long Island, New York.

VANCE, CHAMP SHEPHERD, September, 1910.
Third Vice-President, Los Angeles Gas & Electric Corporation, 645 South Hill Street, Los Angeles, California.

VAN DEN DRIESSCHE, ACHILLES, September, 1910.
Assistant Engineer, Consolidated Gas Company, 124 East 15th Street, New York, New York.

VAN NESS, L. G., October, 1906.
Secretary, The Merchants Power Company, 48 North Second Street, Memphis, Tennessee.

VANDER WILLIGEN, T. A., September, 1908.
Continental Representative of Humphreys & Glasgow, Ltd., 209 Chaussee D'Ixelles, Brussels, Belgium.

VINCENT, G. I., October, 1906.
Engineer, Des Moines Gas Company, 412 7th Street, Des Moines, Iowa.

VONMAUR, JACOB D., October, 1906.
Superintendent of Distribution, Laclede Gas Light Company, 11th and Olive Streets, St. Louis, Missouri.

VON PHUL, WILLIAM, September, 1912.
Member of firm Ford, Bacon & Davis, Engineers, 921 Canal Street, New Orleans, Louisiana.

VON STARZENSKI, VICTOR, March, 1909.
Superintendent, Mohawk Gas Company, 511 State Street, Schenectady, New York.

VONVITTINGHOFF, HANS, September, 1908.
Secretary to Vice-President, Stone & Webster, 147 Milk Street, Boston, Massachusetts.

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VOORHEES, ANDREW JOHN, March, 1913.
Secretary to Vice-President, Brooklyn Union Gas Company, 180 Remsen Street, Brooklyn, New York.

WAGNER, FRED H., March, 1907.
Engineer, Gas Light Company of Augusta (Ga.), 1429 Madison Avenue, Baltimore, Maryland.

WAINWRIGHT, ARTHUR V., October, 1906.
General Manager, American Public Service Company, Abilene, Texas.

WALDRON, CHARLES, JR., September, 1908.
Assistant Manager, Kingston Gas & Electric Company, 611 Broadway, Kingston, New York.

WALKER, EDWIN M., October, 1906.
General Manager, Union Electric Company, Dubuque, Iowa.

WALKER, M. T., October, 1906.
Manager, Beaumont Gas Light Company, Beaumont, Texas.

WALLACE, R. A., October, 1906.
Manager, Quebec Gas Company, Quebec, Canada.

WALLACE, ROSS STRAWN, March, 1913.
Second Vice-President and General Manager, Peoria Gas & Electric Company, 316 South Jefferson Avenue, Peoria, Illinois.

WALLACE, SCOTT HENRY, September, 1912.
Assistant General Manager, St. Louis County Gas Company, Lockwood and McClure Avenues, Webster Groves, Missouri.

WALTER, E. P., September, 1913.
Engineer, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

WALTERS, BENJ. S., October, 1906.
Manager, Northern Indiana Gas & Electric Company, 215 South Michigan Street, South Bend, Indiana.

WARING, GEORGE H., October, 1906.
Vice-President and General Manager, Charleston Consolidated Railway & Lighting Company, 141 Meeting Street, Charleston, South Carolina.

WARMINGTON, DANIEL R., October, 1906.
1804 East 63d Street, Cleveland, Ohio.

WARNER, GEORGE H., October, 1906.
Secretary and Treasurer, William M. Crane Company, 16 West 32d Street, New York, New York.

WARNICK, JOHN H., September, 1908.
Superintendent of Manufacture, Omaha Gas Company, 20th and Centre Streets, Omaha, Nebraska.

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WATERBURY, HERBERT JESSUP, September, 1910.
Manager, Marquette Gas Light Company, Marquette, Michigan.

WATERS, JOHN A., October, 1906.
Assistant Superintendent, Gas Department, The Stamford Gas & Electric Company, 805 Atlantic Street, Stamford, Connecticut.

WAY, ALEXANDER B., September, 1911.
Chief Chemist, New England Gas & Coke Company, Everett, Massachusetts.

WEBER, F. C., September, 1910.
Engineer, 243 Crosby Street, Akron, Ohio.

WEBER, THEO. J., September, 1908.
Consulting Engineer, United Light & Railway Company, 823 Michigan Trust Building, Grand Rapids, Michigan.

WEHNER, ADOLPH FREDERICK, October, 1906.
Secretary, Isbell-Porter Company, 46 Bridge Street, Newark, New Jersey.

WEHNERT, H. C., September, 1913.
Superintendent, Station A, Laclede Gas Light Company, Laclede Gas Building, 11th and Olive Streets, St. Louis, Missouri.

WEISGERBER, EDWIN C., October, 1906.
General Manager, Cedar Rapids Gas Light Company, Third Street and Fourth Avenue, Cedar Rapids, Iowa.

WELCH, JOHN S., October, 1906.
Manager, Industrial Division, The United Gas Improvement Company, 1035 Market Street, Philadelphia, Pennsylvania.

WELCH, WILLIAM MCNAIR, October, 1906.
Mechanical Engineer, The Mexican Eagle Oil Company, Tampico, Mexico.

WELSH, WILLIAM J., October, 1906.
President and Manager, New York & Richmond Gas Company, 694 Bay Street, Stapleton, New York.

WERNER, LOUIS H., September, 1910.
Secretary, Central Union Gas Company, 519 Courtlandt Avenue, New York, New York.

WESTCOTT, JOHN TOWNSEND, October, 1906.
Consulting Engineer, 11 Strawberry Hill Road, Twickenham, London, England.

WESTON, EDGAR C., September, 1912.
Superintendent, Gas Light Company, 240 Court Street, Middletown, Connecticut.

WHEELER, FRED B., October, 1906.
Gas Engineer, H. M. Byllesby & Company, Insurance Exchange Building, Chicago, Illinois.

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WHEELER, H. A., September, 1907.
Agent, Gas and Electric Departments, Public Service Gas Company, 27 West 8th Street, Bayonne, New Jersey.

WHIPPLE, HENRY S., October, 1906.
Manager, Rockford Gas Light & Coke Company, 201 Mulberry Street, Rockford, Illinois.

WHITCOMB, H. D., October, 1906.
General Manager, Public Service Gas Company, Room 608, Public Service Building, Newark, New Jersey.

WHITE, ALFRED H., September, 1909.
Professor of Chemical Engineering, University of Michigan, 715 Church Street, Ann Arbor, Michigan.

WHITE, HENRY H., October, 1906.
504 Waldorf Apartments, Seattle, Washington.

WHITE, JOHN T., March, 1911.
Superintendent of Street Main Department, Brooklyn Union Gas Company, 5 Skillman Street, Brooklyn, New York.

WHITELEY, BENJAMIN, September, 1908.
Assistant Treasurer, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

WHITNEY, ROY FOXWELL, March, 1910.
General Manager and Treasurer, Peoples Gas & Electric Company, 70 East First Street, Oswego, New York.

WHITTAKER, ALAN DEAN, October, 1910.
Superintendent of Works, Atlanta Gas Light Company, 38 Thurmond Street, Atlanta, Georgia.

WHITTON, W. H., October, 1906.
Secretary and Treasurer, Laclede Gas Light Company, 11th and Olive Streets, St. Louis, Missouri.

WHITWELL, L. M., March, 1909.
General Superintendent, Semet-Solvay Company, Syracuse, New York.

WHITWELL, SANFORD N., September, 1912.
General Auditor, Washington Gas Light Company, Post Office Drawer 817, 415 10th Street, N. W., Washington, District of Columbia.

WHYSALL, GEORGE, October, 1906.
Consulting Engineer, Hamilton (Ontario) Gas Light Company, Marion, Ohio.

WILDE, CHARLES, March, 1908.
Engineer of Mains, Philadelphia Suburban Gas & Electric Company, 6th and Welsh Streets, Chester, Pennsylvania.

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WILDER, STUART, September, 1912.
Vice-President and General Manager, Northern Westchester Lighting Company, First Avenue and First Street, Mt. Vernon, New York.

WILEY, LYMAN A., March, 1910.
Secretary, Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

WILKE, ARNO C., March, 1909.
Chemist, Milwaukee Gas Light Company, 1025 Third Street, Milwaukee, Wisconsin.

WILKINSON, A. L., October, 1906.
Treasurer, National Gas, Electric Light & Power Company, 1714 Ford Building, Detroit, Michigan.

WILLARD, FRED A., March, 1907.
With Corrigan & Company, Michigan Trust Building, Grand Rapids, Michigan.

WILLIAMS, E. H., October, 1906.
Agent and Superintendent, United Gas Improvement Company, Waterbury, Connecticut.

WILLIAMS, HERBERT G., October, 1906.
Manager, Peoples Gas Company, Pottstown, Pennsylvania.

WILLIAMS, LUTHER S., October, 1906.
Manager, Harrisburg Gas Company, Harrisburg, Pennsylvania.

WILLIAMS, WILLIAM L., October, 1906.
Engineer (Retired), Public Service Gas Company, 63 Twelfth Avenue, Paterson, New Jersey.

WILLIAMSON, JOHN, October, 1906.
Vice-President and Consulting Engineer, Peoples Gas Light & Coke Company, 122 South Michigan Avenue, Chicago, Illinois.

WILLIS, CHARLES M., March, 1907.
Assistant Gas Engineer, J. G. White Management Corporation, Operating Department, 43 Exchange Place, New York, New York.

WILLS, JOHN VALENTINE, September, 1911.
Superintendent of Gas Works, Indiana Lighting Company, Barr and Superior Streets, Fort Wayne, Indiana.

WILSON, G. J., October, 1906.
Fort Tryon Hall, 196th Street and Fort Washington Avenue, New York, New York.

WILSON, H. H., March, 1907.
Manager, Wausau Gas Company, Wausau, Wisconsin.

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WILSON, RODNEY M., September, 1912.
Chief Draughtsman, Department of Mains and Services, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

WILSON, W. A., October, 1906.
Superintendent, Rockford Gas Light & Coke Company, Rockford, Illinois.

WING, JOHN FRANKLIN, March, 1908.
Superintendent, Everett Station, Boston Consolidated Gas Company, Everett, Massachusetts.

WITHERBY, EDWIN C., October, 1906.
General Superintendent, Semet-Solvay Company, Syracuse, New York.

WITHERBY, EDWIN E., October, 1906.
District Manager, General Vehicle Company, 612 Otis Building. La Salle and Madison Streets, Chicago, Illinois.

WOLFF, SAMUEL E., October, 1906.
Care of Hodenpyl, Hardy & Company, 14 Wall Street, New York, New York.

WOOD, STUART, October, 1906.
Treasurer, Macon (Ga.) Gas Light & Water Company, 400 Chestnut Street, Philadelphia, Pennsylvania.

WOOD, WILLIAM AUSTIN, October, 1906.
First Vice-President and Engineer-in-Chief, Boston, Consolidated Gas Company, 24 West Street, Boston, Massachusetts.

WOOD, WILLIAM MUSGRAVE, September, 1907.
The United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

WOODALL, GEORGE HERBERT, September, 1908.
General Manager and Engineer, Brooklyn Borough Gas Company, Surf Avenue and West 12th Street, Coney Island, New York.

WOODS, GEORGE E., October, 1906.
Assistant Chief Engineer, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

WORTENDYKE, I. F., October, 1906.
Superintendent, New Gas Light Company, 7 North Main Street, Janesville, Wisconsin.

WORTHING, LEIGH E., September, 1911.
Chief Chemist, Detroit City Gas Company, Gas Office Building, Detroit, Michigan.

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WRIGHT, E. J. H., October, 1906.
Secretary and Manager, Northwestern Gas Light & Coke Company, 115 North Oak Park Avenue, Oak Park, Illinois.

WRIGHT, W. H., October, 1906.
Engineer of Operation, United Coke & Gas Company, 6 Church Street, New York, New York.

WRIGHTINGTON, EDGAR N., October, 1906.
Secretary and Manager, Commercial Department, Boston Consolidated Gas Company, 24 West Street, Boston, Massachusetts.

WUEST, HENRY ANDREW, September, 1908.
Chief Clerk, Brooklyn Union Gas Company, Foot North 12th Street, Brooklyn, New York.

WYANT, ROBERT E., October, 1906.
Engineer, New Haven Gas Light Company, 80 Crown Street, New Haven, Connecticut.

WYMAN, WALTER S., September, 1912.
Treasurer and General Manager, Central Maine Power Company, 311 Water Street, Augusta, Maine.

YOUNG, ALFRED W., October, 1906.
Superintendent, Knoxville Gas Company, Knoxville, Tennessee.

YOUNG, JOHN T., March, 1907.
General Manager, Grand Rapids Gas Light Company, Grand Rapids, Michigan.

YOUNG, PERCY S., October, 1906.
Comptroller, Public Service Gas Company, 763 Broad Street, Newark, New Jersey.

YOUNG, PETER, October, 1906.
Vice-President and General Manager, Washington Gas Light Company, 315 10th Street, N. W., Washington, District of Columbia.

YOUNG, R. R., October, 1906.
General Agent, Public Service Gas Company, 575 Broad Street, Newark, New Jersey.

YOUNG, ROBERT W. H., March, 1911.
Superintendent of Works, Consolidated Gas Company, 3300 Second Avenue, Pittsburgh, Pennsylvania.

ZEEK, CHARLES F., October, 1906.
Superintendent, Pensacola Gas Company, 27 East Garden Street. Pensacola, Florida.

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ASSOCIATE MEMBERS.

AHLBRANDT, G. F., March, 1913.
Metallurgical Engineer, American Rolling Mill Company, Middletown, Ohio.

AIKIN, HUGH CARLTON, October, 1906.
Eastern Sales Manager, Eclipse Gas Stove Company, 11th and Madison Streets, Chester, Pennsylvania.

ANNETT, EDWARD BURDETT, September, 1911.
Inspector of Gas, Public Utility Commission, State of New Jersey, 738 Broad Street, Newark, New Jersey.

ASENDORF, CARL F., October, 1906.
Representative, Charles H. Dickey & Company, 38 South Jefferson Street, Chicago, Illinois.

ATWATER, C. G., October, 1906.
Engineer, American Coal Products Company, 17 Battery Place, New York, New York.

AUE, JOSEPH E., October, 1906.
Mechanical Engineer, with De La Vergne Machine Company, Foot of East 138th Street, New York, New York.

AZOY, ANASTASIO, C. M., October, 1906.
Manager, Berwind-White Coal Mining Company, 1 Broadway, New York, New York.

BALDWIN, ABRAM T., September, 1912.
President and General Manager, Precision Instrument Company, 102 Randolph Street, Detroit, Michigan.

BALZ, GEORGE ADAM, March, 1911.
Manager, Didier-March Company, Gas Engineers, Perth Amboy, New Jersey.

BARBOUR, WILLIAM TEFFT, October, 1906.
President, Detroit Stove Works, 1320 Jefferson Avenue, Detroit, Michigan.

BARTLETT, JOHN CRAWFORD, September, 1908.
President, Bartlett & Company, Inc., 1938 Market Street, Philadelphia, Pennsylvania.

BEHRINGER, EDWARD A., October, 1906.
94 Warren Street, New York, New York.

BERRY, F. K., October, 1906.
President, A. B. Stove Company, Battle Creek, Michigan.

BETTLE, WILLIAM H., March, 1908.
Superintendent, Appliance Department, Century Stove & Manufacturing Company, 415 San Pedro Street, Los Angeles, California.

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BIGELOW, LUCIUS SEYMOUR, October, 1906.
Editor, *The Gas Industry,* 64 Pearl Street, Buffalo, New York.

BINGHAM, R. W., October, 1906.
Contract Agent, Welsbach Street Lighting Company of America. Peoples Gas Building, Chicago, Illinois.

BLINKS, WALTER M., October, 1906.
Assistant Manager, General Gas Light Company, Park and Water Streets, Kalamazoo, Michigan.

BOOTHE, GEORGE P., October, 1906.
Superintendent, S. R. Dresser Manufacturing Company, Boylston Street, Bradford, Pennsylvania.

BRILL, ALFRED P., October, 1906.
General Manager, Ruud Manufacturing Company, 29th and Smallman Streets, Pittsburgh, Pennsylvania.

BROWN, WILLIAM LAIRD, September, 1912.
Assistant Manager, Helme & McIlhenny, 1339 Cherry Street, Philadelphia, Pennsylvania.

BUCKLEY, JOHN C., October, 1906.
Traveling Salesman, George M. Clark & Company Division, American Stove Company, 179 North Michigan Avenue, Chicago, Illinois.

BUELL, WM. C., JR., September, 1909.
Secretary and General Manager, Westmacott Gas Furnace Company, 9 Codding Street, Providence, Rhode Island.

BUNNELL, STERLING H., October, 1906.
Engineer-in-Chief, Griscom-Russell Company, 90 West Street, New York, New York.

CALDWELL, JAS. HENRY, September, 1909.
President, Ludlow Valve Company, Troy, New York.

CARPENTER, FRANK, March, 1911.
Commercial Department, Welsbach Gas Lamp Company, 392 Canal Street, New York, New York.

CARPENTER, H. A., October, 1906.
Vice-President, Riter-Conley Manufacturing Company, 56 Water Street, Pittsburgh, Pennsylvania.

CARTWRIGHT, HENRY R., October, 1906.
Manager, Philadelphia Factory, American Meter Company, Arch and 22d Streets, Philadelphia, Pennsylvania.

CAVENAGH, FRANK, March, 1911.
Western Representative, C. H. Dickey & Company, 1811 Peoples Gas Building, Chicago, Illinois.

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CHAPIN, EDWIN S., March, 1908.
Vice-President, Welsbach Gas Lamp Company, 392 Canal Street, New York, New York.

CHEESMAN, FRANK P., October, 1906.
Partner, Cheesman & Elliot, 100 William Street, New York, New York.

CHISHOLM, CHARLES T., October, 1906.
Traveling Representative, General Gas Light Company, Kalamazoo, Michigan.

CLADER, WILLIAM A., March, 1912.
Secretary and General Manager, The Audit Company of Philadelphia, 1125 Land Title Building, Philadelphia, Pennsylvania.

CLAIBORNE, CHAS. H., March, 1909.
General Sales Manager, Union Mining Company, Manufacturers Mount Savage Fire Brick, 1113 Fidelity Building, Baltimore, Maryland.

CLARK, CHARLES J., March, 1911.
Vice-President, Hunter & Dickson Company, 245 Arch Street, Philadelphia, Pennsylvania.

CLIFFORD, THOMAS C., October, 1906.
General Agent, Pittsburgh Meter Company, East Pittsburgh, Pennsylvania.

CONROY, JAMES P., March, 1913.
Manager, General Gas Light Company, 46 West Broadway, New York, New York.

COOKE, HORACE G., September, 1913.
Sales Agent, Connersville Blower Company, 114 Liberty Street, New York, New York.

CORBUS, F. G., October, 1906.
Superintendent, Retail Departments, Welsbach Company, United Gas Improvement Company Building, Broad and Arch Streets, Philadelphia, Pennsylvania.

CRESSLER, ALFRED M., October, 1906.
Treasurer, The Kerr Murray Company, Peoples Gas Building, Chicago, Illinois.

CRESSLER, GEORGE H., October, 1906.
Sales Manager, The Kerr Murray Company, Peoples Gas Building, Chicago, Illinois.

CRUSE, ARTHUR R., October, 1906.
Manager, Cruse Engineering Company, Trenton, New Jersey.

DALY, DAVID R., October, 1906.
Vice-President and Treasurer, J. H. Gautier & Company, Green and Essex Streets, Jersey City, New Jersey.

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DANIELS, CLARENCE F., March, 1911.
Salesman, Detroit Stove Works, 2921 LaSalle Street, Chicago, Illinois.

DEHART, J. S., JR., October, 1906.
President, Isbell-Porter Company, 46 Bridge Street, Newark, New Jersey.

DICKEY, EDMUND S., October, 1906.
Member of Charles H. Dickey & Company, Guilford Avenue and Saratoga Street, Baltimore, Maryland.

DOUGHERTY, CHARLES, September, 1910.
Air Compressor and Pneumatic Tool Salesman, Ingersoll-Rand Company, 11 Broadway, New York, New York.

DREW, WILLIAM THOMAS, March, 1911.
Vice-President and Superintendent, New York Improved Meter Company, Inc., 306 East 47th Street, New York, New York.

EARNSHAW, WARNER G., September, 1908.
General Sales Manager, Barnes & Tucker Company, 213 Harrison Building, Philadelphia, Pennsylvania.

EISENMAN, F. N., September, 1908.
District Sales Manager, Gulf Refining Company, 110 State Street, Boston, Massachusetts.

ELMER, CHARLES BLISS, September, 1913.
Vice-President and Treasurer, General Gas Appliance Company, 103 Park Avenue, New York, New York.

ESAU, RALPH, October, 1906.
Manager of Sales, Barrett Manufacturing Company, 1200 Otis Building, Chicago, Illinois.

FAIRCHILD, SAMUEL E., JR., September, 1912.
President, Cruse-Kemper Company, Ambler, Pennsylvania; 6910 West Wissahickon Avenue, Mt. Airy, Philadelphia, Pennsylvania.

FISHER, THOMAS J., October, 1906.
Superintendent Street Lighting, Washington Gas Light Company, District Building, Washington, District of Columbia.

FOERSTERLING, DR. H., September, 1909.
Second Vice-President, Roessler & Hasslacher Chemical Company, High Street, Perth Amboy, New Jersey.

FOWLER, J. SCOTT, October, 1906.
Vice-President, Deily & Fowler Manufacturing Company, 39 Laurel Street, Philadelphia, Pennsylvania.

FRAMPTON, R. C., March, 1907.
President, Pittsburgh Water Heater Company, Pittsburgh, Pennsylvania.

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FRANCISCO, ELLSWORTH, September, 1913.
Inspector of Gas and Gas Meters, City Hall Annex, Newark, New Jersey.

FRANKLIN, WILLIAM B., September, 1909.
Western Sales Manager, U. S. Cast Iron Pipe and Foundry Company, 1203 Morris Building, Philadelphia, Pennsylvania.

FRITZ, H. C., March, 1909.
Manager, Schneider & Trenkamp Division, American Stove Company, Cleveland, Ohio.

GARRISON, JOHN J., October, 1906.
Vice-President, Rathbone Sard & Company, North Ferry Street, Albany, New York.

GASSETT, A. L., October, 1906.
Care of Trenkamp Stove & Range Company, 9806 Quincy Avenue, Cleveland, Ohio.

GOODMAN, PATRICK, October, 1906.
Manager, Safety Gas Main Stopper Company, 257 East 133d Street, New York, New York.

GRIBBEL, W. GRIFFIN, September, 1912.
Assistant Manager, J. J. Griffin & Company, 1513 Race Street, Philadelphia, Pennsylvania.

HAEHNLEN, JACOB L., September, 1912.
With Laclede Gas Light Company, 11th and Olive Streets, St. Louis, Missouri.

HAMERSTROM, FREDERICK NATHAN, March, 1911.
Commercial Department, Welsbach Company, Gloucester, New Jersey.

HAMLINK, L. C., October, 1906.
Vice-President, Gas Machinery Company, 1900 Euclid Avenue, Cleveland, Ohio.

HARPER, H. D., October, 1906.
Western Manager, American Meter Company, 1811 Peoples Gas Building, Chicago, Illinois.

HAYWARD, E. BARTLETT, March, 1907.
Assistant General Manager, Bartlett, Hayward & Company, Scott and McHenry Streets, Baltimore, Maryland.

HAYWARD, STERLING F., October, 1906.
Treasurer, Connelly Iron Sponge & Governor Company, 127 Duane Street, New York, New York.

HENRY, WILLIAM G., October, 1906.
Vice-President, Detroit Stove Works, Detroit, Michigan.

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HERBERT, FREDERICK D., September, 1911.
General Sales Manager, Terry Steam Turbine Company, 90 West Street, New York, New York.

HICKS, GEORGE CLEVELAND, JR., October, 1906.
Vice-President and Mechanical Engineer, P. H. & F. M. Roots Company, Box 165, Connersville, Indiana.

HIGGINS, C. M., October, 1906.
Representative, The Standard Oil Company, 26 Broadway, New York, New York.

HINMAN, WALTER HIBBARD, March, 1911.
Gas Meter Engineer, American Meter Company, 11th Avenue and 47th Street, New York, New York.

HOBDELL, GEORGE, October, 1906.
Manager, Phoenix Meter Company, 107 Arch Street, Camden, New Jersey.

HODSON, H. M., March, 1909.
Mechanical Engineer Bryan, Donkin Company, Ltd., Parliament Mansions, Victoria Street, Westminster, S. W., London, England.

HOFFMAN, JULES G., October, 1906.
Jules G. Hoffman Company, 1124 Majestic Building, Detroit, Michigan.

HOHMANN, AUGUST B., September, 1911.
Sales Manager, C. J. Tagliabue Manufacturing Company, Bush Terminal, 32 33d Street, Brooklyn, New York.

HORNSEY, JOHN W., September, 1910.
Consulting Engineer, Searles, California.

HUBBS, JOHN HENRY, September, 1908.
Assistant Purchasing Agent, The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

HULTS, EUGENE ARTHUR, March, 1913.
Sales Agent, General Electric Company, 1005 Monadnock Block, Chicago, Illinois.

HUTCHINSON, WILLIAM P., March, 1912.
Vice-President and Sales Manager, Sprague Meter Company, 205 Water Street, Bridgeport, Connecticut.

HYDE, EDWARD P., March, 1910.
Director, Physical Laboratory, National Electric Lamp Association, General Electric Company, Post Office Box 387, Nela Park, Cleveland, Ohio.

ISBELL, CHARLES W., October, 1906.
President, Board of Directors, Isbell-Porter Company, 257 Broadway, New York, New York.

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JOHNSTON, E. D., October, 1906.
President, P. H. & F. M. Roots Company, Connersville, Indiana.

KAHN, JULIUS, March, 1907.
General Manager, New York Metal Hose Company, 42 Broadway, New York, New York.

KAHN, LAZARD, October, 1906.
Vice-President, Estate Stove Company, Hamilton, Ohio.

KANE, WILLIAM, October, 1906.
President, William Kane Manufacturing Company, 1909 Adams Street, Philadelphia, Pennsylvania.

KELLUM, BENJAMIN J., October, 1906.
Manager, Western Department, Welsbach Company, 141 North Wabash Avenue, Chicago, Illinois.

KIRCHBERGER, MORITZ, September, 1909.
President, Crescent Burner Company, 374 Second Avenue, New York, New York.

KNIGHT, WILLIAM H., October, 1906.
General Manager, Cleveland Gas Meter Company, 2180 East 65th Street, S. E., Cleveland, Ohio.

KOPPERS, HENRY, October, 1907.
President, H. Koppers Company, Constructors of By-Products and Gas Ovens, 5 South Wabash Avenue, Chicago, Illinois.

LANSINGH, VAN RENSSELAER, September, 1909.
Nelite Works of General Electric Company, 6523 Euclid Avenue, Cleveland, Ohio.

LAUBER, ALBERT, October, 1906.
Treasurer, Standard Meter & Manufacturing Company, 433 West 42d Street, New York, New York.

LEAKEY, NATHAN G., October, 1906.
Assistant Secretary, Michigan Ammonia Works, Detroit, Michigan.

LEAMY, ALAN, October, 1906.
Manager, Middle West Department, Welsbach Company, 116 East Chestnut Street, Columbus, Ohio.

LEMOINE, LOUIS R., September, 1913.
President, United States Cast Iron Pipe & Foundry Company, 1421 Chestnut Street, Philadelphia, Pennsylvania.

LEWIS, ELLIS R., March, 1911.
President, National Gas Light Company, Kalamazoo, Michigan.

LEWIS, THOMAS L., September, 1913.
Assistant Manager of Sales, A. M. Byers Company, 235 Water Street, Pittsburgh, Pennsylvania.

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LITLE, THOMAS J., JR., October, 1906.
Engineer, Welsbach Company, Gloucester City, New Jersey.

LITTLE, ARCHIBALD S. B., September, 1907.
General Manager, Consolidated Gas Purification & Chemical Company, Nashville, Tennessee.

LOCKWOOD, W. A., October, 1906.
General Salesman, Ringen Stove Company, 414 South Sixth Street, St. Louis, Missouri.

LUEDER, CARL GEORGE, March, 1911.
Secretary and Treasurer, New York Improved Meter Company, Inc., 306 East 47th Street, New York, New York.

LUSH, JOSEPH, October, 1906.
President, New York Improved Meter Company, 306 East 47th Street, New York, New York.

LYON, EDWARD A., September, 1908.
District Sales Manager, Gulf Refining Company, 814 Battery Park Building, New York, New York.

MCCLELLAN, JOHN W., September, 1908.
Vice-President and General Manager, Manhattan Gas Heating Company, 909 Seventh Avenue, New York, New York.

MCCOY, WILLIAM P., March, 1911.
Commercial Department, Welsbach Company, Gloucester, New Jersey.

MCDONALD, FREDERICK, September, 1909.
Gas Meter Manufacturer, 991 Broadway, Albany, New York.

MCILRAVY, W. N., October, 1906.
Vice-President, Barrett Manufacturing Company, 17 Battery Place, New York, New York.

MCNARY, JOHN B., October, 1906.
Manager and Secretary, Canadian Meter Company, Limited, Hamilton, Ontario, Canada.

MACBETH, NORMAN, September, 1909.
Illuminating Engineer; Editor, *Lighting Journal*; 166 West 72d Street, New York, New York.

MASON, JOHN AMBLER, September, 1909.
With the Bartlett, Hayward Company, 100 Broadway, New York, New York.

MASON, SIDNEY, October, 1906.
President, Welsbach Company, United Gas Improvement Company Building, Broad and Arch Streets, Philadelphia, Pennsylvania.

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MELCHER, CHARLES W., October, 1906.
General Manager, Ingersoll-Rand Company of Illinois, Peoples Gas Building, Chicago, Illinois.

MILLAR, P. S., March, 1909.
Assistant Manager and Secretary, New York Electrical Testing Laboratories, 80th Street and East End Avenue, New York, New York.

MILLER, FRED A., October, 1906.
President and General Manager, S. R. Dresser Manufacturing Company, Boylston Street, Bradford, Pennsylvania.

MINGUS, JAMES B., March, 1910.
Sales Agent, Penn Gas Coal Company, 222 South Third Street, Philadelphia, Pennsylvania.

MORDUE, THOMAS N.
Coal Merchant, 817 Peoples Gas Building, Chicago, Illinois.

MORLEY, ROBERT L., March, 1908.
Western Manager, The Michigan Stove Company, 439 South Clinton Street, Chicago, Illinois.

MORRELL, CLARENCE P., October, 1906.
Wholesale Coal, Room 194, 1 Broadway, New York, New York.

MUELLER, ROBERT, October, 1906.
Secretary, H. Mueller Manufacturing Company, Decatur, Illinois.

NEWBOLD, E. S., March, 1909.
President, American Street Lighting Company, 831 Greenmount Avenue, Baltimore, Maryland.

NICHOLLS, CARROLL B., October, 1906.
Assistant Secretary, Westmoreland Coal Company, 224 South Third Street, Philadelphia, Pennsylvania.

NORTON, ARTHUR E., October, 1906.
Superintendent, Nathaniel Tufts Meter Company, 455 Commercial Street, Boston, Massachusetts.

NORTON, HARRY A., October, 1906.
President and Manager, Nathaniel Tufts Meter Company, 455 Commercial Street, Boston, Massachusetts.

NUTTY, G. R., October, 1906.
General Sales Manager, Gulf Refining Company, Frick Building Annex, Pittsburgh, Pennsylvania.

O'NEIL, W. D., March, 1911.
Tulsa, Oklahoma.

OSBORNE, WILLARD B., October, 1906.
Gas Engineer, Riter-Conley Manufacturing Company, 56 Water Street, Pittsburgh, Pennsylvania.

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OSIUS, GEORGE, October, 1906.
Secretary and Treasurer, Michigan Ammonia Works, Detroit, Michigan.

PAGE, EDWARD, September, 1908.
Secretary, New England Gas & Coke Company, 111 Devonshire Street, Boston, Massachusetts.

PAPWORTH, HARRY M., September, 1913.
Salesman and Eastern Manager, P. H. & F. M. Roots Company, 120 Liberty Street, New York, New York.

PARISH, WILLIAM H., March, 1913.
Sales Engineer, Westmoreland Coal Company, 224 South 3rd Street, Philadelphia, Pennsylvania.

PARKER, GEORGE W., October, 1906.
Eastern Agent, Parker-Russell Mining & Manufacturing Company, 45 Broadway, New York, New York.

PARKER, JOHN F., September, 1910.
Western Sales Manager, Eclipse Gas Stove Company, Rockford, Illinois.

PATTERSON, ALFRED R., September, 1912.
Auditor, Stone & Webster Management Association, 147 Milk Street, Boston, Massachusetts.

PATTISON, MELVIN, October, 1906.
General Manager of Sales, Brown Hoisting Machinery Company, 4403 St. Clair Avenue, Cleveland, Ohio.

PAYNE, F. H., October, 1906.
Manager, Metric Metal Works, 10th and Payne Streets, Erie, Pennsylvania.

PECK, HARRY G., September, 1913.
Treasurer, Gas Appliance Sales Company of America, 18 South 7th Street, Philadelphia, Pennsylvania.

PEFFLY, IRVIN W., September, 1908.
Eastern Sales Manager, George M. Clark Company, Division American Stove Company, 1493 Broadway, New York, New York.

PERKINS, ROWAN P., September, 1907.
Mechanical Engineer; Manufacturer of Gas Appliances, 122 North 11th Street, Philadelphia, Pennsylvania.

PERRY, A. T., October, 1906.
Vice-President, Barrett Manufacturing Company, 1210 Williamson Building, Euclid Avenue, Cleveland, Ohio.

PHILLIPS, L. R., March, 1907.
Care of National Tube Company, 1307 McCormick Building, Chicago, Illinois.

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PILZ, C., March, 1907.
Secretary, New York Lead Wool Company, 93 Nassau Street, New York, New York.

PISER, THEO. H., October, 1906.
Manager, Welsbach Company of New England, 16 Oliver Street, Boston, Massachusetts.

PLANTINGA, PIERRE, October, 1906.
President, The Gas Machinery Company, 1900 Euclid Avenue, Cleveland, Ohio.

PLUCKER, HOWARD W., September, 1910.
Salesman, with I. A. Sheppard & Company, Erie Avenue and Sepviva Street, Philadelphia, Pennsylvania.

PORTER, ROLAND G., October, 1906.
Chemist-Engineer, Riter-Conley Manufacturing Company, Lowell, Massachusetts.

POTTER, CLIFFORD C., March, 1910.
Manufacturer's Agent, Agent for Detroit Graphite Company, Room 702, 135 Broadway, New York, New York.

PRATT, HENRY, October, 1906.
President, Henry Pratt Boiler & Machine Company, 2222 South Halsted Street, Chicago, Illinois.

PRENDERGAST, DANIEL J., October, 1906.
General Superintendent, Welsbach Street Lighting Company of America, 318 West 42d Street, New York, New York.

PRICE, W. W., October, 1906.
President, The Dayton Pipe Coupling Company, 435 East First Street, Dayton, Ohio.

RANCKE, LOUIS N., October, 1906.
Consulting Engineer and Chemist, 107 North Carey Street, Baltimore, Maryland.

REEVES, WILLIAM, October, 1906.
President, The Reeves Manufacturing Company, Milford, Connecticut.

REICHHELM, PAUL F., September, 1908.
Secretary, American Gas Furnace Company, 24 John Street, New York, New York.

REYNOLDS, M. G., October, 1906.
President and General Manager, Reynolds Gas Regulator Company, 1019 Delaware Street, Anderson, Indiana.

ROBERTS, CLARENCE V., October, 1906.
President, Roberts & Mander Stove Company, 11th Street and Washington Avenue, Philadelphia, Pennsylvania.

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RODGERS, EDWARD H., October, 1906.
President and Treasurer, Standard Meter Company, 3112 North 17th Street, Philadelphia, Pennsylvania.

ROESCH, DANIEL, October, 1906.
Instructor in Mechanical Engineering, Armour Institute of Technology, Armour Station, 33rd Street and Armour Avenue, Chicago, Illinois.

ROLSTON, ROBERT J., March, 1911.
Manager, Welsbach Company, 1008 Filbert Street, Philadelphia, Pennsylvania.

RUST, ROBERT RIPLEY, March, 1910.
Superintendent of Foundries, Central Foundry Company, 90 West Street, New York, New York.

RUUD, EDWIN, September, 1907.
Manufacturer, Ruud Manufacturing Company, Pittsburgh, Pennsylvania.

SALT, THOMAS V., September, 1910.
418 Church Street, Evanston, Illinois.

SANDERS, BARNEY H., September, 1912.
President and General Manager, American Foundry & Manufacturing Company, St. Louis, Missouri.

SARD, RUSSELL E., September, 1909.
Treasurer, Rathbone, Sard & Company, Albany, New York.

SAYER, EUGENE Y., October, 1906.
Vice-President and General Manager, Improved Equipment Company, 60 Wall Street, New York, New York.

SCHALL, HENRY D., October, 1906.
Assistant to Vice-President, Detroit Stove Works, 1320 Jefferson Avenue, Detroit, Michigan.

SCHMIDLAPP, W. H., September, 1909.
President, Monitor Stove & Range Company, Cincinnati, Ohio.

SCHURZ, JAMES R., September, 1907.
General Sales Agent, Camden Coke Company, 755 Broad Street, Newark, New Jersey.

SEAVER, KENNETH, September, 1913.
Chief Engineer and Assistant General Sales Manager, Harbison-Walker Refractories Company, Farmers Bank Building, Pittsburgh, Pennsylvania.

SEEGER, ROBERT, October, 1906.
District Manager, Welsbach Street Lighting Company of America, 704 Laclede Gas Building, St. Louis, Missouri.

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SENGER, HERBERT, September, 1913.
Eastern Representative, Consolidated Gas Purification & Chemical Company, 101 Park Avenue, New York, New York.

SHEPPARD, HOWARD R., September, 1909.
Member of firm of I. A. Sheppard & Company, 1801 North 4th Street, Philadelphia, Pennsylvania.

SMITH, ARTHUR M., October, 1906.
Treasurer, The Gas Machinery Company, 1900 Euclid Avenue, Cleveland, Ohio.

SMITH, T. J., JR., March, 1911.
Special Sales Representative, Pittsburgh Water Heater Company, Pittsburgh, Pennsylvania.

SPELLER, FRANK N., March, 1907.
Metallurgical Engineer, National Tube Company, Frick Building, Pittsburgh, Pennsylvania.

SPRAGUE, HENRY H., March, 1908.
President, Sprague Meter Company, 205 Water Street, Bridgeport, Connecticut.

STACEY, ANDREW J., October, 1906.
Assistant General Manager, The Stacey Manufacturing Company, Station P, Cincinnati, Ohio.

STACEY, JAMES E., October, 1906.
President, The Stacey Manufacturing Company, Station P, Cincinnati, Ohio.

STITES, TOWNSEND, September, 1907.
General Manager, Welsbach Company, Gloucester, New Jersey.

STONE, THOMAS W., October, 1906.
Engineer, Western Gas Construction Company, Buchanan Street, Fort Wayne, Indiana.

STORRS, AARON PUTNAM, March, 1908.
President, Storrs Mica Company, Owego, New York.

STORRS, CHARLES P., October, 1906.
Secretary, Storrs Mica Company, Owego, New York.

SULLIVAN, EDWARD J., March, 1908.
Firm of Sullivan Brothers, 45 Main Street, Flushing, Long Island, New York.

SULLIVAN, WILLIAM H., March, 1908.
Firm of Sullivan Brothers, 45 Main Street, Flushing, Long Island, New York.

TAPLIN, FRANK E., October, 1906.
President, Cleveland & Western Coal Company, Leader Building, Cleveland, Ohio.

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TATMAN, J. S., March, 1911.
With Connersville Blower Company, Connersville, Indiana.

TAYLOR, H. G., October, 1906.
Assistant Engineer, Lawrence Gas Company, 370 Essex Street, Lawrence, Massachusetts.

THOMAS, RICHARD H., October, 1906.
President, Thomas, Roberts, Stevenson Company, Third and McKean Streets, Philadelphia, Pennsylvania.

TIMM, CHARLES F., March, 1911.
Salesman, Wm. M. Crane & Company, 16 West 32d Street, New York City, 46 Point Street, Yonkers, New York.

TRENKAMP, H. J., October, 1906.
President, Trenkamp Stove & Manufacturing Company, 9806 Quincy Avenue, Cleveland, Ohio.

TRIPP, FRANK FOSTER, September, 1913.
Treasurer, Automatic Gas Lighting Equipment Company, 247 Atlantic Avenue, Boston, Massachusetts.

TUFTS, BOWEN, September, 1912.
Director, various gas companies, 78 Devonshire Street, Boston, Massachusetts.

UMMACH, CHARLES E., October, 1906.
President, Ummach Manufacturing Company, 65 East Lake Street, Chicago, Illinois.

VAN WIE, EDWIN, G., October, 1906.
Superintendent, Gas Appliance Department, Detroit Stove Works, 1320 Jefferson Avenue, Detroit, Michigan.

VAN WINKLE, W. H., September, 1913.
Vice-President, Water Works Equipment Company, 50 Church Street, New York, New York.

WARDELL, CHAS. W., September, 1909.
Illuminating Engineer, Welsbach Company, Gloucester, New Jersey.

WARREN, HENRY J., October, 1906.
President, Stamford Gas Stove Company, Box 388, Stamford, Connecticut.

WAY, JOHN G., March, 1909.
Manager, New Process Stove Company Division, American Stove Company, 4415 Perkins Avenue, Cleveland, Ohio.

WEBER, ALBERT J., October, 1906.
President, Adam Weber Sons, Manhattan Club, 26th and Madison Avenues, New York, New York.

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WEHNER, ROBERT K., October, 1906.
Treasurer, Isbell-Porter Company, Bridge and Ogden Streets, Newark, New Jersey.

WELLER, WILLIAM W., September, 1913.
Manager of Sales, A. M. Byers Company, Pittsburgh, Pennsylvania.

WELLS, FRED K., October, 1906.
Manager, Pittsburgh Water Heater Company of Massachusetts, 69 Broad Street, Boston, Massachusetts.

WESTERMAIER, FRANCIS VICTOR, October, 1906.
Engineer, Welsbach Street Lighting Company of America, Broad and Arch Streets, Philadelphia, Pennsylvania.

WHARTON, HENRY, October, 1906.
Secretary, Westmoreland Coal Company, 224 South Third Street, Philadelphia, Pennsylvania.

WHITAKER, M. C., October, 1906.
Professor, Mechanical Science, Columbia University, New York, New York.

WHITE, CHAS., March, 1909.
Member of firm of White & Middleton Gas Engine Company, Charles and Winder Streets, Baltimore, Maryland.

WICKHAM, LEIGH, October, 1906.
Sales Agent, Parker-Russell Mining & Manufacturing Company, 501 Liggett Building, St. Louis, Missouri.

WILLIAMSON, RICHARD, September, 1908.
President, R. Williamson Company, 88 West Washington Street, Chicago, Illinois.

WILMOT, JAS. EDW., September, 1909.
Manager, Gas Tip & Self-Lighter Company, 149 Church Street, New York, New York.

WILPUTTE, LOUIS, March, 1913.
Vice-President, United Coke & Gas Company, 6 Church Street, New York, New York.

WILSON, EDWARDS F., October, 1906.
Chief Chemist, Westmoreland Coal Company, Irwin, Pennsylvania.

WILSON, JOHN CROSIER, September, 1911.
Engineer, Thomas Meter Department, Cutler-Hammer Manufacturing Company, 12th Street and St. Paul Avenue, Milwaukee, Wisconsin.

WITTE, LOUIS A., September, 1913.
Engineer, Didier-March Company, Perth Amboy, New Jersey.

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WOOD, EDWARD R., JR., October, 1906.
Machinery Sales Manager, R. D. Wood & Company, 400 Chestnut Street, Philadelphia, Pennsylvania.

YOUNG, L. B., October, 1906.
Assistant General Manager, The Michigan Stove Company, 1022 Jefferson Avenue, East, Detroit, Michigan.

YOUNG, N. A., March, 1909.
Secretary, James Gardner, Jr., Company, Lincoln Street, Bolivar, Pennsylvania.

YOUNGMAN, ROBERT H., September, 1910.
Assistant to President, Harbison-Walker Refractories Company, 1816 Farmers Bank Building, Pittsburgh, Pennsylvania.

ZITZEWITZ, HERMANN, October, 1906.
President, National Machine Works, 10 Sheffield Avenue, Chicago, Illinois.

ZWISLER, A. L., October, 1906.
President, American Gas Light Company, Kalamazoo, Michigan.

Total Associate Members 221

JUNIOR MEMBERS.

ALBURGER, ELMER R., September, 1908.
Special Inspector of Appliances, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

BALDWIN, FREDERICK R., September, 1912.
Superintendent's Assistant, Brooklyn Union Gas Company, 150 Sixth Avenue, Brooklyn, New York.

BARNES, GEO. J., March, 1909.
Foreman, 25th Ward Works, The United Gas Improvement Company, Richmond and Tioga Streets, Philadelphia, Pennsylvania.

BAXTER, EDW. O., September, 1908.
Chief Clerk, Westchester Lighting Company, 67 North Broadway, Yonkers, New York.

BAYLIE, WILLIAM PERCIVAL, September, 1913.
Inspector of Accounts, Distribution Department, Philadelphia Gas Works, 24 North 22d Street, Philadelphia, Pennsylvania.

BEEBE, THOMAS RUSSELL, September, 1907.
Commercial Engineer, 1417 Morse Avenue, Chicago, Illinois.

BENNITT, GEORGE E., September, 1913.
Engineer's Assistant, Department of Utilization, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

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BURNETT, FREDERICK, October, 1906.
Assistant to Chief Engineer, Economical Gas Apparatus Construction Company, 269 Front Street, East, Toronto, Ontario, Canada.

BURTON, LAWRENCE V., March, 1912.
Instructor, University of Illinois, 303 Green Avenue, Champaign, Illinois.

BYRNE, THOMAS J., September, 1912.
Superintendent's Assistant, Consolidated Gas Company of New York, 501 East 21st Street, New York, New York.

CALKINS, W. B., October, 1906.
Chemist, Fuel Testing Company, 220 Devonshire Street, Boston, Massachusetts.

CALL, ALMON EUGENE, September, 1912.
Retort House Foreman, Lynn Gas & Electric Company, 20 Beacon Hill Avenue, Lynn, Massachusetts.

CALLAHAN, CORNELIUS F., September, 1913.
Foreman Fitter, Old Colony Gas Company, Weymouth, Massachusetts.

CALLAHAN, JOHN JOSEPH, March, 1911.
Draughtsman, New York & Richmond Gas Company, 694 Bay Street, Stapleton, New York.

CALLAWAY, GEORGE SAMUEL, September, 1912.
Superintendent's Assistant, Equity Works, Brooklyn Union Gas Company, Porter and Maspeth Avenues, Brooklyn, New York.

CHADWICK, WALTER C., September, 1913.
Assistant Engineer of Mains, Philadelphia Suburban Gas & Electric Company, Chester, Pennsylvania; 5014 Hazel Avenue, Philadelphia, Pennsylvania.

CHIDSEY, RAYMOND F., September, 1911.
Mechanical Engineer, Jenkintown Division, Philadelphia Suburban Gas & Electric Company, Wyncote, Pennsylvania.

CHRISTY, HENRY B., October, 1906.
Fitters' Foreman, United Gas Improvement Company, 1102 Foulkrod Street, Frankford, Philadelphia, Pennsylvania.

COLES, SIDNEY S., September, 1913.
Assistant to Engineer, Westchester Lighting Company, 1st Avenue and 1st Street, Mount Vernon, New York.

COLLIER, EDWARD CARLTON, March, 1913.
With Missoula Gas Company, Missoula, Montana.

COOMBS, FRED S., October, 1906.
Superintendent, Meter Department, Youngstown Gas & Electric Company, Post Office Box 58, Youngstown, Ohio.

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CRAMMOND, WILLIAM ALEXANDER, March, 1911.
227 Fullum Street, Montreal, Quebec, Canada.

CRANKSHAW, J. WARD, March, 1910.
Allentown Gas Company, Allentown, Pa.

CREEDEN, JOHN J., March, 1911.
Chief Clerk, General Fuel Appliance Department, Consolidated Gas Company, 130 East 15th Street, New York, New York.

CRESSLER, KERR MURRAY, October, 1906.
Assistant to Engineer, The Kerr Murray Company, Peoples Gas Building, Chicago, Illinois.

CROWELL, JAMES KENNETH, September, 1908.
Assistant to Engineer, Westchester Lighting Company, Portchester, New York.

DAVIS, E. B., March, 1909.
Cadet, Distribution Department, Westchester Lighting Company, 134 South 11th Avenue, Mt. Vernon, New York.

DICKEY, PHILIP S., March, 1912.
Foreman Fitting Shop, Beloit Water, Gas & Electric Company, 563 East Grand Avenue, Beloit, Wisconsin.

DUNCAN, HOWARD WILLIAM, September, 1912.
Superintendent, Northern Indiana Gas & Electric Company, Plymouth, Indiana.

EICHENGREEN, LEON B., March, 1913.
With Counties Gas & Electric Company, Ardmore, Pennsylvania.

ELLIS, R. L., March, 1913.
Superintendent, Selma Lighting Company, Selma, Alabama.

FARR, RILEY WILLIAM, JR., March, 1912.
Superintendent of Electric Construction, Northern Westchester Lighting Company, Box 224, Ossining, New York.

FELTON, JOHN GARRETT, March, 1912.
Cadet Engineer, Fulton County Gas & Electric Company, 18 East Fulton Street, Gloversville, New York.

FIELD, HORACE HOPKINS, September, 1911.
Superintendent, Connecticut Power Company, 33 Union Street, New London, Connecticut.

FITZPATRICK, DANIEL, October, 1906.
Foreman of Works, St. Augustine Gas & Electric Light Company, St. Augustine, Florida.

FORD, CHARLES MCCABE, March, 1913.
Chief Clerk and Assistant General Foreman, Brooklyn Union Gas Company, 5th and Hoyt Streets, Brooklyn, New York.

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Fox, Charles J., October, 1906.
Superintendent of Distribution, Philadelphia Suburban Gas & Electric Company, 867 Main Street, Darby, Pennsylvania.

Gellert, Nathan H., March, 1911.
Constructing Gas Engineer, care of Public Service Construction Company, San Juan, Porto Rico.

Gibson, James Coe, September, 1912.
Secretary-Treasurer and Manager, Labette Gas Company, Chetopa, Kansas.

Gonzalez, Americo Rodriguez, March, 1913.
Inspector of Lighting, Havana Electric Railway, Light & Power Company, Monte 1, Havana, Cuba.

Grant, Albert W., Jr., September, 1913.
Cadet Engineer, United Gas Improvement Company, 2316 South 21st Street, Philadelphia, Pennsylvania.

Green, Albert, October, 1906.
General Foreman of Fitters, The United Gas Improvement Company, 4251 Romain Street, Philadelphia, Pennsylvania.

Green, J. W., October, 1906.
Superintendent, Westchester Lighting Company, First Avenue and First Street, Mount Vernon, New York.

Greene, Raymond Lewis, March, 1913.
Assistant Superintendent, Brooklyn Union Gas Company, 556 Kent Avenue, Brooklyn, New York.

Griffin, Orange G., September, 1913.
Draughtsman, Consolidated Gas Company, 1854 Seventh Avenue, New York, New York.

Griffis, Rowland Elliot, September, 1913.
Inspector of Traffic Handling, Philadelphia Gas Works, United Gas Improvement Company, 24 North 22d Street, Philadelphia, Pennsylvania.

Griffiths, Norman James, September, 1913.
Statistical Clerk, Consolidated Gas Company, 130 East 15th Street, New York, New York.

Gross, Harry O., September, 1909.
Chief Inspector, Street Lighting Department, United Gas Improvement Company, 24 North 22d Street, Philadelphia, Pennsylvania.

Haldeman, Clifford L., September, 1911.
District Main Foreman, Philadelphia Gas Works, 2942 North Bambray Street, Philadelphia, Pennsylvania.

Hamilton, Earl R., September, 1911.
Chemist, Lowell Gas Light Company, Lowell, Massachusetts.

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HAMMOND, ERIC W., October, 1906.
Superintendent of Meter Shop, Kansas City Gas Company, 910 Grand Avenue, Kansas City, Missouri.

HANSEN, ALFRED H., September, 1912.
Tar Salesman, Omaha Gas Company, 416 Woolworth Avenue, Omaha, Nebraska.

HARRIMAN, HERBERT E., September, 1912.
Superintendent of Works, Bangor Gas Light Works, 349 Main Street, Bangor, Maine.

HAYWARD, HAROLD A., March, 1911.
Assistant General Manager, Connelly Iron Sponge & Governor Company, 127 Duane Street, New York, New York.

HEAVNER, LEROY CLEMENTS, March, 1911.
Engineer, Tampa Gas Company, Tampa, Florida.

HELMAN, HIRAM, September, 1913.
Superintendent of Mains and Services, Old Colony Gas Company, Quincy Avenue, Weymouth, Massachusetts.

HENSON, EDWARD B., September, 1910.
Assistant Foreman, Gas Plant, San Antonio Gas & Electric Company, San Antonio, Texas.

HILL, DANIEL L., March, 1911.
Superintendent of Records, Toronto Gas Company, 19 Toronto Street, Toronto, Canada.

HOFF, JOHN F., March, 1913.
Superintendent, Public Service Gas Company, 45 Witherspoon Street, Princeton, New Jersey.

HOUSTON, GRAY JONES, March, 1909.
Spokane Falls Gas Light Company, Spokane, Washington.

HOWARD, CHARLES O. S., September, 1912.
Assistant Distribution Foreman, Gas Department, Queens Borough Gas & Electric Company, Far Rockaway, New York.

INNES, J. A., October, 1906.
Secretary and Treasurer, Citizens Light, Heat & Power Company, Eagle Grove, Iowa.

JOHNSTON, ERNEST, October, 1906.
Care of Syracuse Lighting Company, Syracuse, New York.

JONES, LEON B., September, 1912.
Assistant Engineer, Gas Department, Pacific Gas & Electric Company, 445 Sutter Street, San Francisco, California.

KANE, MILFORD L., September, 1911.
Service Foreman, Omaha Gas Company, 1509 Howard Street, Omaha, Nebraska.

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KAWAI, HIDEICHI, September, 1912.
Cadet Engineer, Westchester Lighting Company, First Avenue and First Street, Mount Vernon, New York.

KEELER, EARL E., March, 1912.
General Shop Foreman, Kansas City Gas Company, 910 Grand Avenue, Kansas City, Missouri.

KELLEY, TIMOTHY J., JR., September, 1910.
Foreman of Fitting Shop, Beloit Water, Gas & Electric Company, Beloit, Wisconsin.

KELLOGG, HARRISON B., September, 1909.
Engineer, Westchester Lighting Company, Post Office Box 7, Rye, New York.

KILLGORE, JAMES N., March, 1913.
Assistant Superintendent of Distribution, Public Service Gas Company, 35 Front Street, Newark, New Jersey.

KINGSBURY, I. CLAYTON, March, 1909.
Assistant Superintendent, Distribution Department, Consolidated Gas Company of New York, 429 East 102d Street, New York, New York.

KNOTHE, W. J., October, 1906.
Engineer, Evens & Howard Fire Brick Company, 920 Market Street, St. Louis, Missouri.

KOLLOCK, EDWARD CAMPBELL, March, 1913.
Superintendent, Gas Department, Charleston Consolidated Railway & Lighting Company, 141 Meeting Street, Charleston, South Carolina.

LAFORE, PAUL JULES, September, 1909.
Inspector of Fuel Appliances, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

LEUENBERGER, WALTER ARNOLD, March, 1908.
Superintendent, Tacoma Gas Company, 101 South 10th Street, Tacoma, Washington.

LOUD, ROGER PERKINS, March, 1912.
Manager, Citizens Gas, Electric & Power Company, Nantucket, Massachusetts.

MALAKOFF, JOHN, September, 1912.
Superintendent's Assistant, Westchester Lighting Company, Spring Street, White Plains, New York.

MALIN, J. H., September, 1912.
Storekeeper, Omaha Gas Company, 1202 Howard Street, Omaha, Nebraska.

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MANSFIELD, J. H., March, 1909.
Assistant Superintendent, Consolidated Gas Company, foot of West 66th Street, New York, New York.

MARSH, EDWARD H., September, 1913.
Street Clerk, Queens Borough Gas & Electric Company, Far Rockaway, New York.

MCCARTHY, ALBERT P., March, 1911.
Engineer, Philadelphia Suburban Gas & Electric Company, Coatesville, Pennsylvania.

MILLER, MISS ANNA VIRGINIA, October, 1906.
Demonstration Cooking Lecturer, 1237 Harrison Street, Kansas City, Missouri.

MINARD, EMORY D., September, 1913.
District Foreman, Public Service Gas Company, 118 Main Street, Hackensack, New Jersey.

MORRISON, MARTIN, September, 1912.
Candle-Power and Calorific Inspector, Westchester Lighting Company, 216 North 6th Street, Mount Vernon, New York.

MOYER, WAYNE R., September, 1913.
Assistant Superintendent, Spring Garden District, United Gas Improvement Company, 446 West Martin Street, Roxborough, Philadelphia, Pennsylvania.

MUELLER, ADOLPH F., March, 1910.
Head Bookkeeper, Seattle Lighting Company, Seattle, Washington.

MULLER, HERMAN, JR., September, 1908.
Works Assistant, New York & Richmond Gas Company, 872 Van Duzen Avenue, Stapleton, New York.

MURPHY, ALBERT FRANCIS, September, 1912.
Assistant to Superintendent, Brooklyn Union Gas Company, 5 Skillman Street, Brooklyn, New York.

NASON, FOREST J., September, 1913.
Clerk, Haverhill Gas Light Company, Haverhill, Massachusetts.

NEAL, GEORGE A., JR., September, 1912.
Cadet Engineer, Omaha Gas Company, 1509 Howard Street, Omaha, Nebraska.

NELSON, E. A., March, 1909.
Engineering Assistant of Mains and Services, Consolidated Gas Company of New York, 80 Elizabeth Street, New York, New York.

NETH, JOHN A., October, 1906.
Foreman, Gas Department, Westchester Lighting Company, 45 John Street, Tarrytown, New York.

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O'KEEFFE, JAMES GARWOOD, March, 1908.
Superintendent, Front Street Works, Public Service Gas Company, 26 Front Street, Newark, New Jersey.

ORDISH, T. BRANDON, October, 1906.
Assistant Superintendent, Lansing Fuel & Gas Company, 224 West Maple Street, Lansing, Michigan.

PALMER, ALVA L., September, 1913.
Engineer's Assistant, Department of Utilization, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

PATTERSON, CLEMENT F., September, 1911.
143 North Washington Avenue, Whittier, California.

PEARCE, WILLIAM FAULKNER, March, 1908.
Assistant to Superintendent, United Gas Improvement Company, Richmond and Tioga Streets, Philadelphia, Pennsylvania.

PEDEN, H. L., March, 1909.
Assistant Superintendent, Distribution Department, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

PERKINS, MATTHEW F., September, 1909.
Chief Canvasser, United Gas Improvement Company, 5813 Thompson Street, Philadelphia, Pennsylvania.

PFEIFFER, BERNARD V., September, 1911.
Superintendent of Manufacture, Nashville Gas & Heating Company, 611 Church Street, Nashville, Tennessee.

POSTLES, JOHN V., September, 1913.
Cadet Engineer, Experimental Plant, United Gas Improvement Company, 3101 Passyunk Avenue, Philadelphia, Pennsylvania.

PRICE, WILLIAM H., October, 1906.
Draftsman and Clerk, Providence Gas Company, 93 Georgia Avenue, Providence, Rhode Island.

RASCH, WM. T., March, 1909.
Assistant to Engineer of Utilization, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

REINER, OTTO, September, 1912.
General Foreman, Public Service Gas Company, 41 Front Street, Newark, New Jersey.

REYBURN, JOHN RANDOLPH, September, 1910.
Engineer, Stone & Webster Management Association, 147 Milk Street, Boston, Massachusetts.

REYNOLDS, JAMES FISHER, September, 1913.
Industrial Salesman, Consolidated Gas Company, 30 East 42d Street, New York, New York.

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RHOADS, WILLIAM HENRY, September, 1913.
Engineer's Assistant, Consolidated Gas Company, 44th Street Station, New York, New York.

RIORDAN, DANIEL, March, 1913.
Chief Clerk in Works Office, Consolidated Gas Company, 501 East 21st Street, New York, New York.

RITCHIE, ARTHUR ROBSON, March, 1911.
Acting Superintendent, Consolidated Gas Company, 14th Street and Avenue C, New York, New York.

ROBERSON, JAY C., March, 1913.
Superintendent of Distribution, Public Service Gas Company, 249 East 4th Street, Plainfield, New Jersey.

ROBINSON, CHAUNCEY D., September, 1911.
Sales Representative, Diamond Rubber Company, Broad and Spring Garden Streets, Philadelphia, Pennsylvania.

ROBINSON, RHEA B., March, 1913.
Chemist, Zenith Furnace Company, 5613 Highland Avenue, West Duluth, Minnesota.

RUSSELL, JAMES, September, 1913.
Assistant Chief Draughtsman, United Gas Improvement Company, 3141 North 17th Street, Philadelphia, Pennsylvania.

SCHELL, WILLIAM F., March, 1913.
Superintendent's Assistant, Brooklyn Union Gas Company, Foot North 12th Street, Brooklyn, New York.

SCHLEGEL, CARL A., September, 1913.
Cadet Engineer, Construction Department, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

SCHROEDER, CARL ROBERT, March, 1912.
Cadet Engineer, Distribution Department, Public Service Gas Company, 1045 Bloomfield Street, Hoboken, New Jersey.

SCHUCK, CONRAD, JR., March, 1911.
Assistant Superintendent, Public Service Gas Company, 258 North Park Street, East Orange, New Jersey.

SEELEY, HAROLD K., September, 1913.
Assistant Superintendent, City District, United Gas Improvement Company, 1931 South 9th Street, Philadelphia, Pennsylvania.

SHAUGHNESSY, THOMAS, JR., September, 1912.
Engineer's Assistant, Consolidated Gas Company, 124 East 15th Street, New York, New York.

SHEEHY, JOHN CHARLES, September, 1911.
Queens Borough Gas & Electric Company, 7 State Street, Far Rockaway, New York.

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SHERWOOD, HERBERT, September, 1910.
Acting Superintendent, Westchester Lighting Company, 119 Woodworth Avenue, Yonkers, New York.

SMITH, GEORGE LATHROP, September, 1913.
Assistant Superintendent, West Philadelphia District, United Gas Improvement Company, 4650 Market Street, Philadelphia, Pennsylvania.

SOMMAR, ALBAN M., March, 1913.
Chief Clerk, Savannah Gas Company, Post Office Box 426, Savannah, Georgia.

SPRAU, ROBERT LEE, September, 1912.
Assistant Superintendent, Louisville Gas & Electric Company, 7th and Ormsby Streets, Louisville, Kentucky.

TARRANT, STANLEY G., March, 1912.
Statistician, Westchester Lighting Company, 1st Avenue and 1st Street, Mount Vernon, New York.

TENNEY, GEORGE C., JR., March, 1912.
Mechanical Engineer, Public Service Gas Company, 35 Front Street, Newark, New Jersey.

TINNEY, THOMAS BROWN, March, 1913.
Chemist, United Gas Improvement Company, 303 Lafayette Avenue, Collingdale, Pennsylvania.

TOBIAS, WILLIAM A., September, 1912.
Foreman of Gas Distribution, Mohawk Gas Company, Schenectady, New York.

TOUR, REUBEN S., March, 1912.
Instructor in Gas Engineering, University of California, 1553 LeRoy Avenue, Berkeley, California.

TRAVIS, GEORGE W. LEROY, September, 1912.
Assistant Engineer, Department Mains and Services, Consolidated Gas Company, 124 East 15th Street, New York, New York.

VECKER, SAMUEL P., March, 1912.
Manager, Key West Gas Company, Fleming and Simonton Streets, Key West, Florida.

WAGNER, EDWIN, October, 1906.
Care of Amerillo Gas Company, Amerillo, Texas.

WARNER, CHARLES PIERIE, March, 1910.
Cadet Engineer, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

WHIPPLE, ROBERT H., March, 1913.
Engineering Department, American Gas Company, West Washington Square, Philadelphia, Pennsylvania.

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WHITE, WILLIAM MORSE, March, 1912.
Superintendent, Coke Oven Plant, Philadelphia Suburban Gas & Electric Company, 2503 West Fourth Street, Chester, Pennsylvania.

WILSON, WARD, October, 1906.
Foreman of Distribution, Lynchburg Traction & Light Company, 316 Euclid Avenue, Lynchburg, Virginia.

WISKE, PRESCOTT B., March, 1913.
Superintendent's Assistant, Brooklyn Union Gas Company, 5th and Hoyt Streets, Brooklyn, New York.

WOOD, FRANK A., September, 1912.
7 Florida Street, Dorchester, Massachusetts.

WOODROFFE, WILLIAM P., September, 1911.
191 Garfield Place, Brooklyn, New York.

WRIGHT, WILLIAM GANO, September, 1912.
Street Clerk, Westchester Lighting Company, 119 Woodworth Avenue, Yonkers, New York.

ZOOK, SAMUEL KURTZ, October, 1906.
Superintendent, Public Service Gas Company, Washing and Peace Streets, New Brunswick, New Jersey.

Total Junior Members 141

SUMMARY.

Honorary	4
Life	1
Active	1104
Associate	221
Junior	141
Total	1471

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MEMBERS OF THE AMERICAN GAS INSTITUTE ARRANGED GEOGRAPHICALLY

Alabama

Birmingham	A. H. Ford.
Mobile	Albert F. Kersting.
Selma	R. L. Ellis.

Arkansas

Little Rock	W. F. Booth.

California

Berkeley	Reuben S. Tour.
Fresno	Wm. M. Henderson.
	M. L. Neely.
Jackson	B. E. Letang.
Los Angeles	Robert M. Adams.
	William Baurhyte.
	Jos. M. Berkley.
	W. H. Bettle.
	Henry W. Burkhart.
	W. B. Cline.
	John T. Creighton.
	Addison B. Day.
	William J. Dorr.
	Robt. F. Fitz.
	Charles P. Houghton.
	Charles A. Luckenbach.
	Thomas P. McCrea.
	Frederick Charles Millard.
	C. S. Vance.
Modesto	Frank A. Cressey, Jr.
Oakland	F. A. Leach, Jr.
Pasadena	C. W. Koiner.
San Diego	Henry H. Jones.
San Francisco	John A. Britton.
	Edward C. Jones.
	Leon B. Jones.
	D. E. Keppelmann.
	F. V. T. Lee.
	John Martin.

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California—(*Continued*)

San Francisco	C. O. G. Miller.
	Saml. L. Naphtaly.
San Jose	Robert H. Hargreaves.
	John D. Kuster.
Santa Monica	W. S. Dole.
Searles	John W. Hornsey.
Upland	Isaac C. Baxter.
Whittier	C. F. Patterson.

Colorado

Colorado Springs	Ira Abbott Miller.
Denver	John T. Brady.
	R. Garland Gentry.
	R. G. Griswold.
	M. E. Malone.
	Clare N. Stannard.
	A. F. Traver.
Greeley	Howard C. Estberg.
Pueblo	James M. Dailey.
	C. C. Durkee.

Connecticut

Bridgeport	C. M. Gerdenier.
	Wm. P. Hutchinson.
	Ralph I. Munson.
	A. J. Palmer.
	Geo. W. Roberts.
	H. H. Sprague.
Danbury	George E. Cowperthwaite.
Derby	Chas. H. Nettleton.
	George H. Scranton.
Hartford	B. W. Perkins.
Meriden	Charles A. Learned.
Middletown	Edgar C. Weston.
Milford	William Reeves.
New Haven	J. Arnold Norcross.
	Clarence E. Thompson.
	Robert E. Wyant.
New London	V. E. Bird.
	H. H. Field.
Rockville	William Morgan Lewis.
Stamford	Henry J. Warren.
	John A. Waters.

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Connecticut—(*Continued*)

Torrington	Frank M. Travis.
Waterbury	John D. Alden.
	Alex. J. Campbell.
	E. H. Williams.
Windsor Locks	W. P. Schwabe.

Delaware

Wilmington	Wm. J. McCorkindale.

District of Columbia

Washington	C. Clay Bayly.
	Frederic Egner.
	Thomas J. Fisher.
	Thomas F. Holden.
	James S. McIlhenny.
	Robert L. Middleton.
	T. Symmes Tincher.
	Sanford N. Whitwell.
	Peter Young.

Florida

Jacksonville	Clarence S. Hammatt.
	Harry B. Hoyt.
	David S. Long.
Key West	Carter H. Page, Jr.
	S. P. Vecker.
Ocala	Chas. W. Hunter.
Pensacola	Charles F. Zeek.
St. Augustine	Daniel Fitzpatrick.
	C. L. Lyon.
Tampa	LeRoy C. Heavner.
	Rosco Nettles.

Georgia

Atlanta	P. S. Arkwright.
	Richard C. Congdon.
	F. B. Crowell.
	A. D. Whittaker.
Augusta	Morris D. Schindler.
Columbus	MacDougald Dexter.
Macon	George R. Horning.
Rome	James Ferrier.
Savannah	J. L. Cabell.
	John W. Golden.
	Alban M. Sommar.

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Idaho

Boise	Chas. M. Eyman.
	O. G. F. Markhus.

Illinois

Aurora	I. C. Copley.
	F. M. James.
	P. O'Malley.
	Henry L. Rice.
	C. B. Strohn.
	R. N. Strohn.
Belleville	Harry B. Kircher.
Champaign	Lawrence V. Burton.
Chicago	Knowlton L. Ames.
	C. F. Asendorf.
	Wm. A. Baehr.
	T. R. Beebe.
	R. W. Bingham.
	D. H. Brush, Jr.
	John C. Buckley.
	F. S. Carnes.
	Frank Cavenagh.
	Alfred A. Chichester.
	Mathias Connors.
	Edward G. Cowdery.
	A. D. Cressler.
	A. M. Cressler.
	G. H. Cressler.
	K. M. Cressler.
	C. F. Daniels.
	James E. Davies.
	R. N. Davis.
	Rufus C. Dawes.
	C. L. Day.
	Alfred B. Eaton.
	L. B. Elliott.
	I. C. Elston, Jr.
	F. J. Ely.
	Ralph Esau.
	John H. Eustace.
	Charles H. Evans.
	Albert L. Farr.
	John Ginley.
	H. D. Harper.

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Illinois—(*Continued*)

Chicago	R. B. Harper.
	A. S. Harrington.
	Julian G. Hart.
	W. E. Hartman.
	Homer T. Hirst, Jr.
	Jesse B. Hirst.
	Eugene A. Hults.
	H. R. Hunt.
	William B. Jackson.
	Benjamin J. Kellum.
	Wm. J. Knapp.
	Henry Koppers.
	J. W. Lawlor.
	Henry I. Lea.
	Thomas J. Lucas.
	A. J. Luick.
	F. E. Luther.
	J. N. McCallum.
	N. A. McClary.
	Joseph C. Markley.
	William P. Martin.
	J. E. J. Mayer.
	Charles W. Melcher.
	T. D. Miller.
	Thomas N. Mordue.
	John M. Morehead.
	R. L. Morley.
	Edward E. Morrell.
	Wm. J. Norton.
	H. L. Olds.
	George G. Olmstead.
	Otto E. Osthoff.
	Dudley W. Penington.
	Henry Peters.
	L. R. Phillips.
	Edward G. Pratt.
	Henry Pratt.
	Theo. V. Purcell.
	James A. Rafferty.
	D. G. Ramsay.
	Charles J. Ramsburg.
	Richard Rees.
	S. A. Reinhard.

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Illinois—(*Continued*)

Chicago	Chas. E. Reinicker.
	Irwin Rew.
	Daniel Roesch.
	Rudolph Schenck.
	C. C. Schiller.
	Samuel C. Shaffner.
	Jacob M. Spitzglass.
	W. D. Sweetman.
	Charles E. Ummach.
	F. B. Wheeler.
	Lyman A. Wiley.
	John Williamson.
	Richard Williamson.
	Edwin E. Witherby.
	Herman Zitzewitz.
Decatur	Robert Mueller.
DeKalb	E. S. Davidson.
Dixon	Edward W. Galloway.
	Justin E. Harlow.
East St. Louis	Charles H. Quackenbush.
Elgin	C. H. Dunbar.
Evanston	R. J. Jenks.
	Andrew McIntyre.
	Thomas V. Salt.
Freeport	E. D. V. Dickey.
Joliet	David Elder.
Kewanee	Elmer W. Smith.
Oak Park	Charles W. Bradley.
	H. H. Clark.
	Mathias Britsch.
	Ernest Jacobson.
	E. J. H. Wright.
Peoria	H. E. Chubbuck.
	D. G. Fisher.
	Ross S. Wallace.
Quincy	Harry O. Channon.
	Carl Steinwedell.
Rockford	C. W. Butterworth.
	A. W. Kendall.
	Garnet W. McKee.
	J. F. Parker.
	George D. Roper.
	Henry S. Whipple.

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Illinois—(*Continued*)

Rockford	W. A. Wilson.
Rock Island	Frederick W. Reimers.
South Chicago	W. H. Allen, Jr.
Waukegan	H. T. Crawford.
	George F. Goodnow.

Indiana

Anderson	M. G. Reynolds.
Auburn	Byron H. Danforth.
Columbus	C. M. Keller.
Connersville	George C. Hicks, Jr.
	E. D. Johnston.
	J. S. Tatman.
Elwood	David S. Milne.
Evansville	J. C. Silverthorn.
Fort Wayne	Fred W. Freese.
	Olaf N. Guldlin.
	G. Max Hofmann.
	Lothar Hofmann.
	S. E. Mulholland.
	Thomas W. Stone.
	Orrell O. Thwing.
	John V. Wills.
Franklin	J. S. Dales, Jr.
Gary	Leonard Fitzgerald.
Greencastle	John G. Martin.
Hammond	A. S. Graham.
	H. C. Miller.
	William D. Ray.
Indianapolis	H. M. Chapman.
	Philmer Eves.
	Carl H. Graf.
	Henry Rochat.
	Frank W. Sargeant.
	George Summers.
Lafayette	Wm. I. Battin.
	S. T. Murdock.
Logansport	George M. Dolley.
Marion	Ira C. Covert.
Michigan City	Chester N. Chubb.
	H. V. Armstrong.
Muncie	J. E. Colvin.
	J. H. Maxon.

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Indiana—(*Continued*)

New Albany	James W. Dunbar.
Noblesville	R. H. Lawlor.
Plymouth	Howard W. Duncan.
South Bend	Edw. B. Myers.
	Benj. S. Walters.
Terre Haute	Alfred S. Cooke.
Valparaiso	LeRoy O. Gordon.

Iowa

Boone	H. G. Stillson.
Burlington	Edward D. Clary.
Cedar Rapids	Thomas Suchomel.
	E. G. Weisgerber.
Charles City	R. K. Runner.
Clinton	Thomas Crawford.
Council Bluffs	A. L. English.
Davenport	Hubert C. Blackwell.
	Joseph F. Porter.
Des Moines	T. Bertram Genay.
	Jansen Haines.
	E. H. Martin.
	Emil G. Schmidt.
	W. H. Thomson, Jr.
	G. I. Vincent.
Dubuque	E. W. Eustace.
	George McLean.
Eagle Grove	J. A. Innes.
Fort Dodge	R. M. Parker.
Muscatine	Edw. M. Walker.
Oskaloosa	J. F. Griffin.
Ottumwa	Edw. L. Lambert.
Sioux City	Wm. J. Bertke.
	Leonard L. Kellogg.
Washington	George S. Carson.
Waterloo	Austin Burt.
	N. G. Phelps.
Webster City	Campbell W. Fair.

Kansas

Chetopa	James C. Gibson.
Independence	A. B. Macbeth.
Kansas City	W. H. McKenzie.
Topeka	George J. Swan.
	L. G. Treleaven.

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Kentucky

Hopkinsville	R. A. Field.
Louisville	A. H. Barret.
	William H. Crutcher.
	Geo. H. Harries.
	Frank Huber.
	J. J. Humphreys.
	Donald McDonald.
	Robt. L. Sprau.
	Harry R. Swann.
Richmond	Benj. A. Dougherty.

Louisiana

New Orleans	Ralph L. Crump.
	Geo. H. Davis.
	H. M. Harriman.
	Richmond E. Slade.
	Wm. von Phul.

Maine

Augusta	Walter S. Wyman.
Bangor	Herbert E. Harriman.
	O. A. Merchant, Jr.
Biddeford	Saml. L. Parcher.
Lewiston	John J. Scott.
Milo	Vernon K. Gould.

Maryland

Baltimore	George Beadenkopf.
	Howard Bruce.
	C. H. Claiborne.
	Charles M. Cohn.
	Charles H. Dickey.
	Edmund S. Dickey.
	E. Bartlett Hayward.
	E. S. Newbold.
	L. Irving Pollitt.
	George R. Althen.
	Louis N. Rancke.
	Edward L. Rieha.
	Albert Rosenthal.
	R. S. Scott.
	Carl C. Thomas.
	Fred H. Wagner.
	Charles White.

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Maryland—(*Continued*)

Frederick	J. H. Enright.
Hagerstown	Marshall M. Milton.

Massachusetts

Attleboro	William J. Luther.
Beverly	C. R. Prichard.
Boston	Perry Barker.
	W. B. Calkins.
	Herbert N. Cheney.
	Alfred Clarke.
	Dwight T. Cortis.
	F. N. Eisenman.
	John A. Gould.
	Robert Grant.
	Chas. W. Hunter.
	Wm. J. Lavelle.
	A. D. Little.
	W. E. McKay.
	Arthur E. Norton.
	Harry A. Norton.
	Edward Page.
	Alfred R. Patterson.
	Theo. H. Piser.
	J. R. Reyburn.
	J. L. Richards.
	Frederick P. Royce.
	Howard T. Sands.
	Albert B. Tenney.
	Frank F. Tripp.
	Bowen Tufts.
	Hans von Vittinghoff.
	F. K. Wells.
	William Austin Wood.
	Edgar N. Wrightington.
Brockton	Henry K. Morrison.
Cambridge	Albert M. Barnes.
	J. P. Kennedy.
Charlestown	Samuel J. Fowler.
Dorchester	F. A. Wood.
East Boston	N. W. Gifford.
East Cambridge	Isaac T. Haddock.
Everett	Howell Fisher.
	Robert M. Folsom.

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Massachusetts—(*Continued*)

Everett	J. M. McClellon.
	Alexander B. Way.
	John F. Wing.
Fall River	R. B. Clark.
	Joseph E. Nute.
Fitchburg	Clifton R. Hayes.
	George W. Stiles.
Framingham	George H. Priest.
Harwich Port	J. D. Hackstaff.
Haverhill	Forest J. Nason.
	Charles Otten, Jr.
	F. M. Roberts.
Lawrence	C. J. R. Humphreys.
	Fred H. Sargent.
	H. G. Taylor.
Lowell	R Buckminster.
	Roland G. Porter.
Lynn	Almon E. Call.
	Charles F. Prichard.
Malden	C. E. Paige.
Nantucket	Roger P. Loud.
New Bedford	Robert Lindsay.
	Wm. H. Snow.
Newton	Waldo A. Learned.
Pepperell	C. L. Gerould.
Pittsfield	Harry C. Crafts.
Quincy	Wm. B. Nichols.
Springfield	Benjamin P. Bill.
	Herman Burgi.
	Charles H. Tenney.
Wakefield	Albert B. Morton.
Webster	H. S. Shaw.
Weymouth	Cornelius F. Callahan.
	Hiram Helman.
	Chas. O. S. Howard.
	George P. Smith, Jr.
Winchester	Chas. W. Hinman.
Worcester	Dana D. Barnum.
	Charles Dudley Lamson.

Michigan

Ann Arbor	Henry W. Douglas.
	Alfred H. White.

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Michigan—(*Continued*)

Battle Creek	F. K. Berry.
	D. N. Frazer.
Bay City	Samuel Ball.
Big Rapids	R. Shacklette.
Detroit	Abram T. Baldwin.
	William Tefft Barbour.
	J. W. Batten.
	Warren S. Blauvelt.
	James A. Brown.
	Dwight F. Burritt.
	Irvin Butterworth.
	M. H. Cutcheon.
	V. F. Dewey.
	Alonzo P. Ewing.
	Wm. G. Henry.
	Jules G. Hoffman.
	Ralph A. Jayne.
	George I. Keal.
	Nathan G. Leakey.
	Alfred G. Lloyd.
	Ernest F. Lloyd.
	James T. Lynn.
	J. N. McCallum.
	George Osius.
	W. H. Pearson, Jr.
	Charles S. Ritter.
	Henry D. Schall.
	C. A. Schwarm.
	A. F. Shattuck.
	Otis A. Sinsel.
	B. O. Tippy.
	Chas. W. Tippy.
	Edwin G. Van Wie.
	A. L. Wilkinson.
	Leigh E. Worthing.
	L. B. Young.
Flint	H. M. Eaton.
Grand Rapids	W. A. Aldrich.
	Jos. H. Brewer.
	Glenn R. Chamberlain.
	John Hellen.
	Frank T. Hulswit.
	Jno. A. Hulswit.

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Michigan—(*Continued*)

Grand Rapids	Chas. B. Kelsey.
	Richard Schaddelee.
	Albert G. Schroeder.
	Frederick Seymour.
	Albert I. Snyder.
	T. J. Weber.
	Fred A. Willard.
	John T. Young.
Jackson	W. M. Eaton.
	B. R. Laraway.
Kalamazoo	Walter M. Blinks.
	Frank W. Blowers.
	Charles T. Chisholm.
	J. J. Knight.
	Ellis R. Lewis.
	A. L. Zwisler.
Lansing	D. K. Crighton.
	T. B. Ordish.
Marquette	H. J. Waterbury
Marshall	Carroll Collins.
Port Huron	J. C. Sloan.

Minnesota

Duluth	C. W. Andrews.
Faribault	B. W. Cowperthwait.
Mankato	Robert. E. Brown.
Minneapolis	F. W. Little.
	Frederick C. Shepard.
Red Wing	Howard Bixby.
St. Paul	John P. Crowley.
	Paul Doty.
	D. W. Flowers.
	Ole S. Johnson.
	Bert. F. Pelton.
	George Steinwedell.
	H. B. Stiles.
West Duluth	Rhea B. Robinson.
Winona	Wm. F. Clausen.

Mississippi

Jackson	Raymond H. Smith.
Vicksburg	John J. Gannon.
	Walter J. Phifer.

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Missouri

Boonville	W. E. Sombart.
Excelsior Springs	Saml. W. Henderson.
Independence	Robert S. Miller.
Joplin	B. J. Crahan.
Kansas City	E. L. Brundrett.
	Byron E. Chollar.
	E. W. Hammond.
	A. Hurlburt.
	E. E. Keeler.
	Miss Anna Virginia Miller.
	F. F. Schauer.
	John M. Scott.
	M. M. Sweetman.
	William M. Wood.
Sedalia	H. D. Frueauff.
St. Charles	Lee G. Stealey.
St. Joseph	V. L. Elbert.
St. Louis	Augustin J. Daly.
	John Dell.
	William S. Dodd.
	A. C. Einstein.
	Geo. B. Evans.
	J. L. Haehnlen.
	C. L. Holman.
	W. J. Knothe.
	W. A. Lockwood.
	Donald MacArthur.
	W. D. O'Neil.
	Jesse E. Pipkin.
	Roger W. Polk.
	Daniel R. Russell.
	Barney H. Sanders.
	Robert Seeger.
	E. H. Tinsman.
	Jacob D. von Maur.
	H. C. Wehnert.
	W. H. Whitton.
	Leigh Wickham.
Webster Groves	J. E. Hillemeyer.
	S. H. Wallace.

Montana

Bozeman	Arthur W. Richter.
Helena	G. A. Strain.
Missoula	Edward C. Collier.

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Nebraska

Fremont	W. H. Merritt.
Omaha	G. W. Clabaugh.
	John C. Grey.
	Alfred H. Hansen.
	Milford L. Kane.
	Joseph Lucena.
	J. H. Malin.
	G. A. Neal, Jr.
	Wm. H. Taylor.
	J H. Warnick.

New Hampshire

Concord	A. J. Smith.
Keene	G. M. Rossman.
Manchester	Walter G. Africa.
	Alex. H. Scott.
Nashua	Walter F. Norton.

New Jersey

Atlantic City	Carlton Geist.
Bayonne	H. A. Wheeler.
Burlington	William Strobridge.
Camden	John J. Burleigh.
	George W. Curtis.
	James N. Downey.
	Harry Ellis.
	George Hobdell.
	Thomas Littlehales.
	E. A. Moore.
	Wm. J. Rodgers.
Dover	Seth H. Ely.
East Orange	Conrad Schuck, Jr.
Elizabeth	Roger Crilley.
	Francis Engel.
Glassboro	Charles W. Hoy.
Gloucester City	F. N. Hamerstrom.
	Thomas J. Litle, Jr.
	Wm. P. McCoy.
	Townsend Stites.
	C. W. Wardell.
Hackensack	Emory D. Minard.
	E. C. Roberts.
	Chas. J. Roeser.

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New Jersey—(*Continued*)

Hoboken	Albert F. Ganz.
	W. Greacen, Jr.
	J. P. Henofer.
	C. R. Schroeder.
Jersey City	James Ashworth.
	West Bissell.
	David R. Daly.
	E. J. Donahue.
	F. W. Schmidt.
Long Branch	Fredk. R. M. Cutcheon.
Madison	Fredk. A. Lydecker.
Merchantville	J. A. Callenbach.
Newark	Edward B. Annett.
	William S. Barker.
	William H. Chadwell.
	John A. Clark, Jr.
	J. S. De Hart.
	James P. Dusenberry.
	E. H. Earnshaw.
	H. H. Ferris.
	Ellsworth Francisco.
	H. D. Gillingham.
	W. M. Halsey.
	J. P. Hanlan.
	James N. Killgore.
	Thomas N. McCarter.
	J. G. O'Keeffe.
	W. H. Pettes.
	Otto Reiner.
	Geo. J. Roberts.
	J. McClellan Rogers.
	Jas. R. Schurz.
	Alexander H. Strecker.
	Geo. C. Tenney, Jr.
	Adolph Frederick Wehner.
	Robert K. Wehner.
	H. D. Whitcomb.
	Percy S. Young.
	R. R. Young.
New Brunswick	W. F. Thomas.
	S. K. Zook.
Ocean City	Martin Maloney, 2d.
Passaic	Oliver H. Folger.

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New Jersey—(*Continued*)

Paterson	John Bimson, Jr.
	Theo. Bunker.
	Jas. M. Lane.
	W. H. Rogers.
	William L. Williams.
Perth Amboy	Geo. A. Balz.
	H. Foersterling.
	A. F. Reitmeyer.
	J. Charles Ross.
	Louis A. Witte.
Plainfield	W. R. Causebrook.
	Thomas L. Melick.
	Jay C. Roberson.
Pleasantville	John P. Tompkins.
Princeton	John F. Hoff.
Ridgewood	George S. Soult.
Summit	M. S. Sherwood.
Toms River	B. H. Spangenberg.
Trenton	Charles G. Cook.
	Arthur R. Cruse.
	James H. Galt.
	Frank D. Moses.
West Hoboken	James Kennedy.

New York

Albany	S. P. Cobb.
	F. S. Dunn.
	Wm. G. Furlong.
	John J. Garrison.
	E. P. Gavit.
	Frederick J. Ikena.
	Charles F. Leonard.
	Donald McDonald.
	F. McDonald.
	William McDonald.
	R. E. Sard.
	F. A. Scobel.
Amsterdam	G. D. Conlee.
	W. H. Cooper.
Astoria, L. I.	W. W. Burden.
	C. M. Carbonell.
	W. VanAlan Clark.
	D. S. Hudson.

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New York—(*Continued*)

Astoria	John C. Shaw.
	N. J. Sperling.
	Crist H. Stevick.
Binghamton	Charles W. Bennett.
Brooklyn	Frederick R. Baldwin.
	Fred. S. Benson, Jr.
	Charles Boone.
	John H. Braine.
	Robert Wilder Bush.
	Edward J. Byrne.
	Edward Louis Byrne.
	Thomas E. Byrne.
	George S. Callaway.
	Charles A. Cross.
	Charles Dougherty.
	Guy K. Dustin.
	Charles M. Ford.
	Raymond L. Greene.
	Theodore Haight.
	Edwin D. Jones.
	James H. Jourdan.
	R. C. Kellogg.
	Thos. P. Kennedy.
	Arthur G. King.
	Raymond C. Lewis.
	John D. Logan.
	Henry E. McGowan.
	E. H. Mathews.
	Samuel A. Mills.
	Albert F. Murphy.
	E. J. Murphy.
	William F. Schell.
	Samuel V. Seddon.
	David J. Shepard.
	A. F. Staniford.
	L. S. Stiles.
	Andrew J. Voorhees.
	John T. White.
	Prescott B. Wiske.
	W. P. Woodroffe.
	Edward C. Uhlig.
	H. A. Wuest.

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New York—(*Continued*)

Buffalo	Lucius S. Bigelow.
	H. C. Palmer.
	Walter W. Richardson.
	William S. Riselay.
Canandaigua	V. A. Miller.
Coney Island	Harry J. Dillon.
	Geo. Herbert Woodall.
Far Rockaway	Edw. L. Davies.
	L. A. Howland.
	Carlton Macy.
	Edward H. Marsh.
Flushing	F. R. Smart, Jr.
	M. H. Spear.
	Edw. J. Sullivan.
	W. H. Sullivan.
Geneva	E. H. Palmer.
	George R. Sanford.
Glens Falls	H. M. Collin.
Gloversville	H. B. Bryans.
	John G. Felton.
	Joseph E. Hodgson.
	Louis C. Smith.
Hempstead	O. J. A. Lundblad.
Ithaca	James W. Murdock.
Kingston	Franklin Tobey, Jr.
	Chas. Waldron, Jr.
Little Falls	Henry P. Collins.
Lockport	Charles M. Kaltwasser.
Long Island City	C. Cassels Atwood.
	Clifford S. Fox.
	W. F. Lawrence.
	M. E. Mueller.
	Harry L. Snyder.
	C. G. M. Thomas.
Middletown	C. H. Stone.
Mt. Vernon	Chas. F. Bryant.
	William J. Clark.
	Sidney S. Coles.
	Edgar B. Davis.
	J. W. Green.
	Robert James Jennings.
	Hideichi Kawai.
	Alfred M. Keene.

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New York—(*Continued*)

Mt. Vernon	R. M. Kellogg.
	George T. Macbeth.
	Martin Morrison.
	W. L. Secord.
	Stanley G. Tarrant.
	Stuart Wilder.
Newburgh	A. R. Beal.
New York City	H. C. Abell.
	Walter R. Addicks.
	H. E. Almberg.
	H. W. Alrich.
	J. Charles Andrews.
	J. H. N. Armstrong.
	C. G. Atwater.
	Joseph E. Aue.
	C. T. Ayres.
	Anastasio C. M. Azoy.
	T. S. Barlow.
	F. R. Barnitz.
	William E. Barrett.
	Wm. F. Barrett.
	W. H. Barthold.
	Eugen Becher.
	Edward A. Behringer.
	E. W. Bell.
	George E. Bennitt.
	W. Russell Bogart.
	William H. Bradley.
	James C. Brady.
	Ernest C. Brown.
	H. M. Brundage.
	Martin F. Buckley.
	D. M. Bull.
	Milan R. Bump.
	Sterling H. Bunnell.
	Thos. J. Byrne.
	Elbert P. Callender.
	S. K. Campbell.
	Frank Carpenter.
	Harold Carpenter.
	Robert A. Carter.
	Robert A. Carter, Jr.
	Joseph L. de Castro.

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New York—(*Continued*)

New York City	Dr. Chas. F. Chandler.
	C. H. B. Chapin.
	E. S. Chapin.
	Frank P. Cheesman.
	B. C. Cobb.
	James P. Conroy.
	Horace G. Cooke.
	Marshall Cornine.
	George B. Cortelyou.
	William A. Crammond.
	William M. Crane.
	John J. Creeden.
	Philip Cross.
	William DeFreitas.
	Frederick R. DeVoe.
	J. Alfred Dixon.
	R. M. Dixon.
	George W. Doane.
	Henry L. Doherty.
	Chas. Dougherty.
	F. J. Down.
	William T. Drew.
	Philip Dunne.
	W. K. Eavenson.
	A. B. Eilbeck.
	Arthur H. Elliott.
	Charles B. Elmer.
	Wm. M. Flook.
	James R. Floyd, Jr.
	O. H. Fogg.
	Alfred E. Forstall.
	Charles G. Francklyn.
	Gilbert Francklyn.
	Frank W. Frueauff.
	Lewis B. Gawtry.
	C. J. Gefvert.
	Patrick Goodman.
	W. R. Goudy.
	Malcolm M. Graham.
	Orange G. Griffin.
	Norton J. Griffiths.
	F. E. Haag.

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New York—(*Continued*)

New York City	A. H. Hall.
	Joseph B. Hare.
	W. K. Harrington.
	F. S. Hastings.
	W. J. Hawthorn.
	Harold A. Hayward.
	Sterling F. Hayward.
	Frederick D. Herbert.
	Edward Hering.
	C. M. Higgins.
	Willard F. Hine.
	Walter H. Hinman.
	Thomas F. Hintze.
	Chas. H. Hodges.
	August B. Hohmann.
	Frederic deP. Hone.
	David Leavitt Hough.
	Abram C. Howard.
	William Greely Hoyt.
	Alexander C. Humphreys.
	F. W. Humphreys.
	Jas. F. Hunter.
	Edward B. Hyde.
	Charles W. Isbell.
	C. N. Jelliffe.
	Adolph C. Johnson.
	Mervyn E. Johnston.
	P. R. Jones.
	Edward R. Jourdan.
	Julius Kahn.
	C. F. Keegan.
	Wm. D. Kelley.
	James S. Kennedy.
	I. C. Kingsbury.
	I. Clayton Kingsbury.
	M. Kirchberger.
	Alanson P. Lathrop.
	Albert Lauber.
	Robert E. Livingston.
	Edward G. Love.
	Charles E. Lucke.
	Carl G. Lueder.
	Robert O. Luqueer.

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New York—(*Continued*)

New York City	Joseph Lush.
	E. A. Lyon.
	J. M. McCarthy.
	J. W. McClellan.
	William McClellan.
	Wm. J. McGurty.
	W. N. McIlravy.
	H. B. McLean.
	Emerson McMillin.
	Marion McMillin.
	Norman Macbeth.
	George MacDonald.
	W. L. MacIntosh.
	A. Fred Macklin.
	J. H. Mansfield.
	William D. Marks.
	John A. Mason.
	J. Alex. Mayers.
	Giles W. Mead.
	Preston S. Millar.
	Alten S. Miller.
	Robert C. Miller.
	L. B. Moorhouse.
	Clarence P. Morrell.
	W. Cullen Morris.
	William G. Morris.
	G. P. Morrow.
	E. A. Nelson.
	John F. Nelson.
	Franklin H. Nickerson.
	Edwin North.
	John O'Connell.
	M. Webb Offutt.
	Alva L. Palmer.
	Harry M. Papworth.
	George W. Parker.
	H. L. Peden.
	Irwin W. Peffly.
	J. H. Perkins.
	Frank J. Petura.
	C. Pilz.
	C. C. Potter.
	Daniel J. Prendergast.

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New York—(*Continued*)

New York City	Charles Raabe.
	George G. Ramsdell.
	William W. Randolph.
	Wm. T. Rasch.
	P. F. Reichhelm.
	Hugo B. Reinach.
	James F. Reynolds.
	Wm. H. Rhoads.
	Daniel Riordan.
	Arthur R. Ritchie.
	Chas. D. Robison.
	Robert R. Rust.
	Eugene Y. Sayer.
	Philip J. Schneider.
	Thomas Scofield.
	Herbert Senger.
	Thomas Shaughnessy, Jr.
	Richard Shepard.
	Marvin Shiebler.
	C. C. Simpson.
	Henry Simpson.
	Elliott L. Spencer.
	Arthur W. Stark.
	John Stilwell.
	R. John Titzel.
	G. W. LeR. Travis.
	Lucien P. F. Tull.
	Alfred E. Turner.
	H. L. Underhill.
	A. Van den Driessche.
	W. H. Van Winkle.
	George H. Warner.
	Albert J. Weber.
	Louis H. Werner.
	M. C. Whitaker.
	Benjamin Whiteley.
	Chas. M. Willis.
	Jas. E. Wilmot.
	Louis Wilputte.
	G. J. Wilson.
	S. E. Wolff.
	George E. Woods.
	W. H. Wright.

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New York—(*Continued*)

Niagara Falls	Albert H. Merritt.
Ossining	Riley W. Farr, Jr.
	H. W. Terry, Jr.
Oswego	R. F. Whitney.
Owego	A. P. Storrs.
	Chas. P. Storrs.
Penn Yan	Wm. T. Morris.
Plattsburg	George M. Cole.
Portchester	J. K. Crowell.
	Joseph P. Kane.
Port Washington	John E. Bullard.
Poughkeepsie	E. V. Anderson.
	T. R. Beal.
	Hugh M. Beugler.
	L. H. Scherck.
Rochester	J. C. Collins.
	James B. Eaton.
	Joseph P. Haftenkamp.
	Frank Hellen.
	James T. Hutchings.
	I. Lundgaard.
	Joseph P. MacSweeney.
	A. Parshall.
	Herman Russell.
	Karl A. Schick.
	E. C. Scobell.
	Robert M. Searle.
	C. A. Tucker.
Rye	J. K. Crowell.
	H. B. Kellogg.
Saranac Lake	Charles A. Gruber.
Saratoga Springs	Patrick F. Roohan.
Schenectady	Wm. A. Tobias.
	Henry W. Peck.
	V. vonStarzenski.
Stapleton	John J. Callahan.
	W. M. R. Hammond.
	Robert C. Morris, Jr.
	H. Muller, Jr.
	William J. Welsh.
Syracuse	William H. Blauvelt.
	James C. DeLong.
	S. J. Dickey.

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New York—(*Continued*)

Syracuse	Arthur D. Dudley.
	Ernest Johnston.
	S. C. Singer.
	L. M. Whitwell.
	Edwin C. Witherby.
Tarrytown	Ernest R. Conover.
	John A. Neth.
Troy	James H. Caldwell.
	Henry C. Shields.
Utica	William J. Cahill.
	Herbert Gilmore Johnson.
Watertown	Fred A. Rogers.
	John B. Taylor.
Westchester	J. M. Butler.
	Eugene H. Rosenquest.
White Plains	John Malakoff.
	E. S. Martin.
Yonkers	E. O. Baxter.
	A. M. Knapp.
	Herbert Sherwood.
	Charles F. Timm.
	Wm. G. Wright.

North Carolina

Asheville	H. W. Plummer.
Durham	R. W. Miller.
Greensboro	Charles H. Andrews.
New Bern	F. H. Sawyer.
Winston-Salem	B. N. Sullivan.

Ohio

Akron	F. C. Weber.
Alliance	D. W. Low.
Ashtabula	Frederick W. Stone.
Bucyrus	H. O. Dutter.
Chillicothe	Frederick A. Stacey.
Cincinnati	Norman G. Kenan.
	William A. Miller.
	Charles H. Printz.
	W. H. Schmidlapp.
	Andrew J. Stacey.
	James E. Stacey.
Cleveland	Martin B. Daly.

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Ohio—(*Continued*)

Cleveland	H. C. Fritz.
	C. C. Gartland.
	A. L. Gassett.
	L. C. Hamlink.
	Frank R. Hutchinson.
	Edward P. Hyde.
	William H. Knight.
	V. R. Lansingh.
	Melvin Pattison.
	A. T. Perry.
	Pierre Plantinga.
	Arthur M. Smith.
	W. E. Steinwedell.
	Frank E. Taplin.
	H. J. Trenkamp.
	Daniel R. Warmington.
	J. G. Way.
Columbus	Thomas J. Jones.
	Alan Leamy.
	William R. Powell.
	Henry D. Turney.
Dayton	Edward H. Light.
	George Light.
	W. W. Price.
	Frank M. Tait.
Delaware	Thomas Clive Jones.
Hamilton	Lazard Kahn.
Mansfield	William C. Hedges.
Marion	George Whysall.
Massillon	Edwin Wagner.
Middletown	G. F. Ahlbrandt.
Newark	Melville Gillett.
Warren	George Daugherty.
Youngstown	Fred S. Coombs.

Oregon

Portland	W. B. Foshay.
	Elmon L. Hall.
	Hilmar M. Papst.

Pennsylvania

Allentown	J. Ward Crankshaw.
	John A. Frick.
	A. C. Taylor.

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Pennsylvania—(*Continued*)

Ardmore	Leon B. Eichengreen.
	Howard Hoffman.
	Isaac N. Knapp.
	John L. Mather.
Berwick	L. D. Spragle.
Bethlehem	W. F. Brodnax.
Bolivar	N. A. Young.
Bradford	George P. Boothe.
	Fred A. Miller.
Carbondale	Chas. L. Rowland.
Catasauqua	G. W. Steele.
Chambersburg	L. L. Cadwallader.
Chester	Hugh C. Aiken.
	L. D. Huestis.
	J. D. Shattuck.
	George W. Thomson.
	Wm. M. White.
	Charles Wilde.
Clearfield	Warren Partridge.
Coatesville	A. P. McCarthy.
Collingdale	Thomas B. Tinney.
Darby	Charles J. Fox.
Easton	B. F. Cresson.
	Edwin G. Holzer.
East Pittsburgh	Thomas C. Clifford.
Erie	F. H. Payne.
Greenville	A. C. Hartzell.
Hamburg	A. J. Althouse.
Harrisburg	C. M. Cole.
	Geo. B. Tripp.
	Luther S. Williams.
Holmesburg	Isaac Battin.
Irwin	Edwards F. Wilson.
Johnstown	John E. Morgan.
Kingston	Wm. C. Anderson.
Lebanon	W. H. Merritt.
	Geo. S. Speaker.
Lewistown	Frank P. Duggan.
Norristown	Herbert H. Ganser.
Philadelphia	H. C. Adams.
	E. R. Alburger.
	Walter A. Allison.
	Howard B. Anderson.

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Pennsylvania—(*Continued*)

Philadelphia	F. M. Arthur.
	James Ball.
	Geo. J. Barnes.
	Geo. S. Barrows.
	J. C. Bartlett.
	Henry S. Battin.
	Wm. P. Baylie.
	Albert B. Beadle.
	Walter W. Beaumont.
	Samuel Taylor Bodine.
	Charles O. Bond.
	Cyrus Borgner.
	Albert M. Boyd.
	Wm. L. Brown.
	Charles L. Bruff.
	H. B. Bryans.
	Ervin Calhoun.
	Henry R. Cartwright.
	William A. Castor.
	Walter C. Chadwick.
	Walter L. Chewning.
	Henry B. Christy.
	Wm. A. Clader.
	Charles J. Clark.
	Walton Clark.
	W. W. Cole.
	David J. Collins.
	E. M. Colquhoun.
	H. R. Cook, Jr.
	F. G. Corbus.
	R. C. Cornish.
	J. A. P. Crisfield.
	G. W. Curran.
	Samuel P. Curtis.
	R. E. Dallas.
	P. T. Dashiell.
	H. W. Davies.
	William F. Dorner.
	James B. Douglas.
	W. F. Douthirt.
	Ronald B. Duncan.
	W. G. Earnshaw.
	Owen B. Evans.

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Pennsylvania—(*Continued*)

Philadelphia	Samuel E. Fairchild, Jr.
	Walton Forstall.
	J. Scott Fowler.
	Wm. B. Franklin.
	F. C. Freeman.
	Walter H. Fulweiler.
	William H. Gartley.
	Clarence H. Geist.
	Thomas S. Genay.
	P. H. Gibbons.
	Francis H. Gilpin.
	H. W. Graeff.
	Albert W. Grant, Jr.
	Albert Green.
	John Gribbel.
	W. Griffin Gribbel.
	Rowland E. Griffis.
	H. O. Gross.
	Clifford L. Haldeman.
	Charles F. Hardick.
	C. Willing Hare.
	Geo. M. Harrison.
	William E. Helme.
	G. R. Hemminger.
	J. H. Hubbs.
	Herbert E. Ives.
	Thos. H. Jackson.
	Robert C. James.
	Edwin P. Jones.
	William Kane.
	August C. Klein.
	John Bartleman Klumpp.
	P. J. Lafore.
	W. P. Lane.
	Louis R. Lemoine.
	W. W. Levering.
	Lewis Lillie.
	H. Livingston.
	John McIlhenny.
	John D. McIlhenny.
	Andrew P. Maloney.
	William H. Marshall.
	Sidney Mason.

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Pennsylvania—(*Continued*)

Philadelphia	James B. Mingus.
	F. N. Morton.
	Wayne R. Moyer.
	Joseph B. Meyers.
	Carroll B. Nichols.
	Rollin Norris.
	C. J. O'Donnell.
	William H. Parish.
	Joseph Smith Parker.
	W. F. Pearce.
	J. A. Pearson.
	Harry G. Peck.
	M. F. Perkins.
	Rowan P. Perkins.
	Jos. A. Perry.
	H. W. Plucker.
	Edward Porter.
	John V. Postles.
	Thos. S. Potts.
	Clarence V. Roberts.
	Chauncey D. Robinson.
	Edward H. Rodgers.
	Robert J. Rolston.
	William L. Rowland.
	John M. Ruegenberg.
	John M. Rusby.
	James Russell.
	F. J. Rutledge.
	Carl A. Schlegel.
	J. Fred Seamon.
	Harold K. Seeley.
	William J. Serrill.
	John C. Sheehy.
	Howard R. Sheppard.
	George L. Smith.
	J. H. Smith.
	Charles S. Snyder.
	Jacob W. Stirzel.
	Morris W. Stroud.
	J. Hawley Taussig.
	Nathaniel W. Thomas.
	Richard H. Thomas.
	Paul Thompson.

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Pennsylvania—(*Continued*)

Philadelphia	Fred G. Thorn, Jr.
	Wm. N. Tolman.
	Carrington Cabell Tutwiler.
	E. P. Walter.
	Chas. P. Warner.
	John S. Welch.
	F. V. Westermaier.
	Henry Wharton.
	Robert H. Whipple.
	Edward R. Wood, Jr.
	Stuart Wood.
Pittsburgh	Arthur Booth.
	Alfred P. Brill.
	H. A. Carpenter.
	Albert G. Davis.
	Charles D. Evans.
	R. C. Frampton.
	Joseph F. Guffey.
	William H. Hammon.
	Edw. D. Leland.
	T. L. Lewis.
	R. S. Lord.
	Walter L. McCloy.
	J. C. McDowell.
	John J. Murray.
	G. R. Nutty.
	Willard B. Osborne.
	James H. Reed, Jr.
	Joseph A. Reed.
	Edwin Ruud.
	Kenneth Seaver.
	Thomas J. Smith, Jr.
	Frank N. Speller.
	Samuel B. Stewart.
	Wm. W. Weller.
	Robert W. H. Young.
	R. H. Youngman.
Pottstown	Herbert G. Williams.
Reading	George B. Bains, 3d.
	John H. Keppelman.
Scranton	William McKelvey Marple.
	Worthington Scranton.
	Harold N. Squier.

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Pennsylvania—(*Continued*)

Scranton	E. M. Stack.
Sunbury	George W. Beck.
West Chester	R. H. Dutton.
	William O. Lamson, Jr.
Williamsport	Ernest H. Davis.
	Wm. R. Rhoades.
Wyncote	Raymond F. Chidsey.
	L. R. Dutton.
York	Joseph E. Philbrick.

Rhode Island

Newport	A. K. Quinn.
Pawtucket	William McGregor.
Providence	George E. Allyn.
	W. C. Buell, Jr.
	Edmund Cathels.
	John W. Ellis.
	Earl R. Hamilton.
	Carroll Miller.
	W. H. Price.
Slocums	A. B. Slater.
Woonsocket	Alfred F. Townsend.

South Carolina

Charleston	C. M. Benedict.
	P. H. Gadsden.
	Edward C. Kollock.
	G. H. Waring.
Columbia	S. W. Brown.

South Dakota

Aberdeen	Charles A. Howard.
Deadwood	H. H. Hyde.
Mitchell	E. J. Sherwood.
Sioux Falls	S. E. Linton, Jr.
Watertown	C. H. Bell.

Tennessee

Knoxville	Alfred W. Young.
Memphis	L. G. Van Ness.
Nashville	Frank J. Blake.
	Roger B. Combs.
	G. Maxwell Johnson.
	A. S. B. Little.
	B. V. Pfeiffer.

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Texas

Amerillo	Edwin Wagner.
Austin	H. M. Moore.
Abilene	A. V. Wainwright.
Beaumont	M. T. Walker.
Dallas	Henry C. Morris.
El Paso	Keating Lewis Simons.
Galveston	Chas. S. French.
San Antonio	G. H. Cushman.
	E. E. Eysenbach.
	J. B. Franzini.
	E. B. Henson.
	W. B. Tuttle.

Utah

Salt Lake City	John C. D. Clark.
	Wm. R. Putnam.

Vermont

Burlington	David W. Jardine.
	Frank H. Parker.

Virginia

Charlottesville	H. M. Hantzmon.
Danville	Frank Talbott.
Fredericksburg	B. F. Bullock.
Hampton	F. L. Marshall.
Lynchburg	Albert J. Kohler.
	Ward Wilson.
Norfolk	E. C. Hathaway.
	R. J. Marks.
Portsmouth	B. B. Ferguson.
Richmond	William P. Knowles.
Suffolk	J. Edw. Francis.

Washington

Aberdeen	P. A. Bertrand.
	Norman Smith Burcombe.
Seattle	Edward A. Dieterle.
	N. C. Fancher.
	Frederick K. Lane.
	A. F. Mueller.

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Washington—(*Continued*)

Spokane	B. C. Adams.
	W. A. Bertke.
	G. J. Houston.
Tacoma	Samuel Kahn.
	W. A. Leuenberger.
	William W. Seymour.
	Henry H. White.

West Virginia

Bluefield	Chas. H. Brown.

Wisconsin

Beloit	Philip S. Dickey.
	T. J. Kelley, Jr.
	Robert G. Krumrey.
	B. F. Lyons.
Green Bay	F. E. Newberry.
Janesville	I. F. Wortendyke.
La Crosse	H. Thurston Owens.
Madison	C. F. Burgess.
	John Corscot.
	F. L. Cross.
	Wiley J. Huddle.
	O. L. Kowalke.
	W. A. Richards.
	Arthur W. Richter.
	John St. John.
Milwaukee	John F. Blackie.
	Fred Bredel.
	R. B. Brown.
	Sheldon J. Glass.
	Ewald Haase.
	Henry M. Humphrys.
	R. P. Kraft.
	G. W. Mackie.
	Bryce McAdam.
	John T. Mason.
	David A. Powell.
	John Wallace Shaeffer.
	A. C. Wilke.
	John Crosier Wilson.
Oshkosh	Sinclair Mainland.
	William Mainland.

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Wisconsin—(*Continued*)

Watertown	C. A. Comstock.
Waukesha	H. M. Buck.
	C. Rodman Stull.
Wausau	H. H. Wilson.
Winonah	J. A. Patten.

Belgium

Brussels	T. A. Vander Willigen.

Canada

Calgary	A. I. Payne.
Chatham	P. S. Coate.
Hamilton	John Keillor.
	John B. McNary.
Montreal	Howard E. Mann.
Quebec	R. A. Wallace.
Toronto	Frederick Burnett.
	Arthur Hewitt.
	Daniel L. Hill.
	L. L. Merrifield.
	W. H. Pearson.

Cuba

Havana	George H. Caffrey.
	Americo R. Gonzalez.
	W. E. Mockett.

England

Dudley	A. O. Jones.
Essex	Arthur W. Sumner.
London	F. J. Angell.
	Wm. A. Bone.
	L. D. Carroll.
	Arthur G. Glasgow.
	H. M. Hodson.
	Frederic Thuman.
	John Townsend Westcott.
	Corbet Woodall.
Liverpool	William King.
Nuneaton	George Helps.

Hawaii

Honolulu	Harry L. Strange.

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Japan

Kobe ..... Shosuke Kubo.
Nagoya ..... Sakura Okamoto.
Osaka ..... Chas. P. Cushman.
Tokio ..... Suyekichi Hiramatsu.

Mexico

Mexico ..... Wm. McN. Welsh.

New Zealand

Christchurch ..... R. C. Bishop.

Porto Rico

San Juan ..... Nathan H. Gellert.

South America

Rio de Janeiro..... H. B. Harrop.

Switzerland

Minusio ..... A. E. Boardman.

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SUMMARY—GEOGRAPHICAL.

Alabama	3	North Carolina	5
Arkansas	1	Ohio	46
California	37	Oregon	3
Colorado	10	Pennsylvania	228
Connecticut	26	Rhode Island	11
Delaware	1	South Carolina	5
District of Columbia	9	South Dakota	5
Florida	11	Tennessee	7
Georgia	11	Texas	12
Idaho	2	Utah	2
Illinois	129	Vermont	2
Indiana	43	Virginia	11
Iowa	28	Washington	13
Kansas	5	West Virginia	1
Kentucky	10	Wisconsin	36
Louisiana	5	Belgium	1
Maine	6	Canada	11
Maryland	19	Cuba	3
Massachusetts	78	England	12
Michigan	66	Hawaii Territory	1
Minnesota	15	Japan	4
Mississippi	3	Mexico	1
Missouri	40	New Zealand	1
Montana	3	Porto Rico	1
Nebraska	10	South America	1
New Hampshire	5	Switzerland	1
New Jersey	90		
New York	381	Total	1471

UNIV. OF MICHIGAN,
JUN 9 1914

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